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GLASS FOR OPTICAL INSTRUMENTS WITH ESPECIAL REFERENCE TO TELESCOPE OBJECTIVES.*

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After all the imperfections that can be reached in the block of glass are ground out, it is then ready to be moulded into the proper shape.

Through the kindness of Mr. Mantois of Paris, I have the pleasure to present, in picture form,‡ a photographic history of the 40-inch crown disc for the Yerkes' telescope.

No. 1 shows the block of glass obtained unbroken from the pot on the 26th of January, 1888.

No. 2 shows the block after the gross imperfections had been sawn off. It was in this condition when I saw it later on in the year. It then weighed 240 kilos or about 525 pounds.

No. 3 shows the one side of the block after its first moulding into a decagonal or ten sided shape. No. 4 shows the opposite side.

After this moulding it was again polished and studied, and impurities detected that had to be ground away. The pictures 5 and 6 show opposite sides of the decagon after this second reduction of the material.

Nos. 7 and 8 show still further cutting and Fig. 9 the finished disc.

These manipulations required months of labor, with the result of producing a very fine disc, although it can be readily seen what a large amount of material had to be ground away before it was finally softened into disc form and annealed.

In the case of discs above six inches diameter the mould is so made as to give one side of the crown a convex curve and one side of the flint a concave curve of the approximate radius to be used in the final grinding and polishing; indeed in the case of large discs this is very necessary, as it allows a larger disc to be made of a certain weight of glass, as well as expedites the work of rough grinding.

* Continued from January Number, p. 224.
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‡ See frontispiece opposite.

For moulding discs of considerable diameter, the mould is made in three parts; a flat bottom, and two half rings which are fastened together by a wire around the outside and set loosely on top of the flat base. The mould is then smeared over with gum arabic or other sticky substance and pulverized chalk dusted over the ring and bottom so that the softened glass will not adhere. This mould is now placed in a specially prepared furnace, the lump or block of glass placed in it and then covered over with a specially prepared cover so that the flame cannot reach it direct, as this would mean the destruction of the block of glass. The annealing furnace should be circular, if the disc is circular, but all the furnaces that I have seen are rectangular in shape except a small one built by Mr. Clark for softening down and annealing waste pieces of optical glass, but Mr. Feil and his successor, Mr. Mantois, surround the mould with a circle of fire brick so as to allow for a symmetrical heating and cooling of the glass. The temperature of the furnace is now slowly and carefully raised, otherwise the block of glass would fly to pieces and be ruined. The temperature is raised only high enough to gently soften the glass until it drops down and fills up the mould. The cover can be raised from time to time to watch the progress of the softening and to tell when the disc is ready for the annealing. When the optical glass maker places his products in the highest class, the crown and flint for an objective are always made in the shape of *discs*, but a great deal of optical glass is made in rectangular plates in which case many can be annealed at once. In the case of discs, they are usually polished on the faces, examined carefully and if found satisfactory the glass maker warrants such discs to the purchaser, and if he is not satisfied with them they can be returned. Plates are polished on two opposite edges only, and after examination are placed in first and second classes. Third class pieces are not polished.

But to return to the annealing of the disc in the furnace. This is one of the most difficult of all the operations of the glass maker, for upon the successful annealing of a disc of glass depends much of its value for an objective. The simplest definition of annealing is that the conditions are such during the process of cooling that *every atom of glass may be permitted to assume a natural and unstrained condition with every one of its neighboring atoms.* If the glass is cooled so slowly that this condition is assured, we have a disc that quickly tells its own story when tested by proper optical means, but if the cooling be too rapid, or irregular, or one sided, the annealing is imperfect, the glass is left in a state

of regular or irregular strain and is more or less unfitted for use in optical instruments.

As soon as the glass has softened down into the shape of the mould, the temperature may be brought down rapidly to within a certain limit which is perhaps not far from 1100 or 1200 degrees Fahrenheit, or say one or two hundred degrees above the point of incandescence. At this point the furnace must be closed tight, every avenue for the air to get in or out being luted with clay.

Then comes the difficult task of lowering the temperature so as to allow the particles of glass to arrange themselves *kindly* with one another. Various methods have been adopted; massive brick work in the construction of the annealing furnaces so as to allow of slow and regular cooling, automatic pyrometers which, attached to clock work, regulate the decrease of the temperature; annealing finally in massive copper moulds placed in the center of the furnace, etc., etc., but all having the same end in view, namely, a regular and slow cooling of the glass.

Quite often imperfections are found in the annealed discs which must be ground out, and the disc reannealed a second and even a third time, but in prolonged or repeated annealing, glass has a tendency to devitrify, *i. e.*, lose its transparency and become semi-opaque. The writer has seen some beautiful discs ruined in this way, one of which was about 30 inches in diameter. In annealing large discs this risk is very great, particularly when the process has to be repeated.

After the furnace has cooled down nearly to the temperature of the outside air, the discs or plates may be safely removed.

It would be impossible in the space at our command to go into the minutiæ of this subject, but we will be pleased to answer any inquiries through the columns of this journal.

In our next paper we will give the various methods of testing optical glass.

HOW TO FIND THE ORBIT OF A DOUBLE STAR BY A GRAPHICAL METHOD.

S. W. BURNHAM.

The graphical method of finding the elements of the orbit of a binary star has some very material advantages over any other. If measures of the angles and distances were absolutely exact, then the analytical method would be perhaps better than any

other, because these positions could be represented by one, and only one ellipse which would mark the apparent path of the companion star. There would be no room for the exercise of the judgment of the investigator. He would have nothing to do but determine by direct and positive means, mathematically or otherwise, the ellipse which would exactly pass through the points found by observation. In practice this can never be done. All observations are more or less in error. Everything depends on the skill, and the experience of the observer. If he has devoted his life to the use of the micrometer in double star work, and made everything else in the line of observation with the telescope of secondary importance, then his measures are entitled to the greatest confidence, and to the highest weight. One set of measures by such an observer is of more value than the best that half a dozen observers can do who divide their time and interest in as many different subjects. It is hardly necessary to mention the names of the Struves and of Dembowski as most illustrious examples of devotion and consistency in following for a long series of years a single line of research. The value of such work will endure for all time. Baron Dembowski confined his attention wholly for thirty years to the measurement of double stars; and acquired a most remarkable skill in the use of the micrometer. In my judgment, no astronomer living or dead, can rank with Dembowski as an observer with this instrument. It is the reward, which comes from the efforts of one, perhaps naturally gifted for the work, who preferred to devote all his time and energies to one subject, and to the absolute exclusion of every other.

I do not wish to be understood as instituting any comparison as to the relative importance of this and other departments of astronomical research; but only to call attention to the importance of selecting at the outset some one line of practical work with the telescope, and then keeping that paramount to the end. In these days of remarkable progress and discovery, no astronomer, however zealous or gifted, can divide his energies in several different directions, and accomplish much in any one. The way to the front is a long one, and there is no royal road. A life-time is much too short.

These remarks are pertinent only by way of pointing out the fact that in finding the orbit of a double star, we have to deal with all sorts of material, and some of it of very indifferent quality. The value of the result will largely depend upon the exercise of sound judgment and common sense in deciding what to do with observations more or less inconsistent with each other.

No manipulation of figures by the use of elaborate mathematical formulæ, no application of the method of least squares, or other refinements of investigation will take the place of these qualities so necessary in the solution of other every-day problems. To proceed in this manner intelligently, it is necessary to have a certain familiarity with the skill, experience, instrumental facilities, etc., of the different observers, in order to give each measure used its proper bearing.

It should not be inferred from these remarks that double star measures are in any wise inferior to other observations with any instrument; but it must be borne in mind that the unavoidable errors, quantities so small that they are wholly insensible in themselves, bear a large ratio to the whole distance measured. The mean distance of the components of nearly every rapid binary known does not exceed 1″, and in many cases this quantity is less than 0″.5, and yet a distance of 0″.1, which can scarcely be appreciated with common powers even in the largest telescope, bears a very considerable relation to the whole.

The graphical method of finding the elements of the orbit, strictly speaking, has not been used until within the last half dozen years. Herschel devised a plan which he called by this name, and it has been varied and elaborated by other writers since that time. This method to some extent was a combination of the mathematical and the graphical, but it sacrificed, as the other so-called graphical methods have done, all the special advantages of the latter by the adoption of artificial positions for the real measures, and then building a superstructure upon that imaginary foundation. These artificial positions were obtained by laying down the angles and distances on square-ruled paper, and drawing what was called an interpolating curve through these positions, which when done with proper care was supposed to represent the real positions better than the measures themselves. Then these new positions, as thus corrected, were laid down and the apparent ellipse drawn, from which the various elements were determined by methods partly graphical and partly analytical. The objection to this and all similar plans is, that the basis upon which the whole investigation must necessarily rest, the actual measures themselves, is entirely lost sight of, and the subsequent steps may, and generally do, rest upon a more or less erroneous assumption. It is certain, it seems to me, that nothing can be better to deal with than the real observations as they were made, since one can then proceed intelligently with all the data before him. If it be true in any instance

that the actual measures cannot be thus used to give the best result, it follows, as a matter of course, that it would be better not to use them at all.

It is necessary to have a considerable arc described by the measures in order to get even an approximate orbit. Under no circumstances will an arc of 90° be sufficient. One may as well guess at the period without making even a figure, upon the assumption that the angular motion will on the average continue to be the same for the whole revolution, as to go through the most elaborate analytical investigation. The fact is that a variety of ellipses, differing widely from each other in area, eccentricity, etc., and sometimes circles and other conic sections, will represent in these short arcs the best observations we ever have as well as, and not unfrequently better than, the particular ellipse found by the most laborious process. In other words, the problem is an indeterminate one, and, so far as any one can say from the given data, no one of several hypotheses is more likely to be correct than the others. Such cases should be left for astronomers of the future to deal with when the proper material has been furnished by observers. It is not often that even an arc of 180° is sufficient. The distances may be such that the limit of the apparent ellipse is well defined, but this is not often the case. As a rule we should have not less than 225° for the difference of the extreme position-angles, and in the projection of some orbits 270° is none too much. In all cases the arc must be large enough to define within very narrow limits the dimensions of the apparent ellipse.

The Measures.

All the measures should be carefully collected from original sources, and arranged in chronological order, with the name of the observer, and the number of nights of which each set is a mean. It is desirable to have this list complete, but it by no means follows that all the measures should be used. It will be obvious from an inspection of the tabular arrangement, even if the pair is an easy one, that some of the measures are erroneous, and too poor to be of any use. Generally speaking such observations will be where one would naturally look for them, in the work of comparatively inexperienced observers. Single observations—that is, measures on one night—are always to be regarded with suspicion, since they may be affected with accidental errors of reading the micrometer, etc. Each set of measures should be a mean of not less than three nights' observations. It goes with-

out saying that the best result will be obtained by the use of the good material only. To attempt to divide up the errors, upon any theory of weights or otherwise among all the observations, good, bad and indifferent, simply because they happen to be on record, is illogical in theory, and unsound in practice. No double-star observer has ever lived, and probably never will, who has not made measures under some circumstances which any one acquainted with the subject would be justified in rejecting at once.

When two or more sets of measures in the same year are to be used, a simple mean is usually taken, and that used instead of the measures in detail. It is very important for a clear understanding of the diagram, that it should not be confused with unnecessary lines and positions.

The measures of the pair to be investigated having been collected, the next step is to lay the selected positions down on paper. This should be done on a scale sufficiently large so that they can be accurately put down, and the subsequent measurements made with all necessary exactness. In a general way the scale should be such that the major axis of the final ellipse will be at least eight or ten inches long. In close pairs, 0″.1 would represent one or two inches. For this purpose a semi-circular protractor with arm and vernier reading to tenths of degrees or less will be necessary for the laying down of the position-angles; and a standard rule twelve or fifteen inches in length, divided into tenths, with a thin beveled edge, for laying down the distances. Having selected a sufficiently large sheet of plain drawing paper two lines are accurately drawn across it at right angles to each other, to represent the four quadrants, and the extremities of these lines are marked 0°, 90°, 180° and 270°. With the protractor accurately centered at the intersection of these lines, and the quadrants made to coincide, the several position-angles are laid down; and lastly the respective distances in close pairs to the nearest hundredth of a second, on these lines or their continuations. We now have a series of positions lying probably on both sides of any ellipse which can be drawn to represent them. The scale of distances used should be put on the drawing so that it may be reduced with the orbit if it should be desired to do this subsequently in the camera.

The Ellipse.

We now come to the most difficult part of the whole operation, and that is to draw the ellipse which shall represent the observa-

tions as perfectly as possible, giving due preference to those which under all the conditions are entitled to the most weight, and at the same time make the areas approximately proportional to the times.

At first sight this looks like a very hard thing to do, but with some practice in this direction, one can at the first attempt, from an inspection of the figure as a whole, fix the foci of the trial ellipse so that the subsequent changes will be small in amount. It is not necessary to actually draw an ellipse on the paper until the major axis and the eccentricity have been roughly determined by passing a point around where the boundary of the figure would be, and watching its path through the several positions.

I have experimented a great deal with all the devices for drawing ellipses, and will say briefly that so far as I know, no instrument has ever been made which is of any practical use for describing ellipses. All the appliances for this purpose are too limited in their application to be of any value. A practical ellipsograph should describe anything between a circle and a straight line, and with any value for the major axis up to the limit of the instrument.

I have found, therefore, that with some modification, the old-fashioned way of using some kind of cord and two fixed points to be better than anything else. If the ellipse is not very eccentric, a strong silk thread will answer the purpose if carefully used so as to make the tension uniform. If the ellipse is very elongated, a very fine wire, soft and thoroughly annealed, is much better, as it will not stretch or yield to any sensible extent. A very fine wire, such as is used in artificial flower making, I have found well adapted to this purpose. For one of the foci I use a fine needle which passes through a fixed loop in the wire just large enough to admit it. For the other focus, a sharp steel wire, with an eye through it which will be in the plane of the diagram when the needle is driven into the drawing board, is necessary. A small sewing-machine needle, which has an eye in just the right place, answers the purpose.

[*To be Continued.*]

ARCTURUS.

DANIEL KIRKWOOD.

With the exception of Sirius, Arcturus is the brightest star visible in our latitude. It is among the few stars mentioned in the Bible, (Job xxxviii: 32). The proper motions of the fixed

stars were first discovered by Dr. Halley in 1717. All observers know the configuration of bright stars called the "Dipper." The handle forms a curve, which continued southward some twenty degrees, points out Arcturus. The parallax has been estimated at 0″.13. The velocity through space is 375 miles per second,* or more than one million miles per hour. That the stars differ very greatly in their volumes cannot be doubted. Indeed we have good reasons for supposing our Sun to be a relatively small body in comparison with many of the giant globes to which our vision is nightly turned. Placed at the distance of Arcturus, its apparent magnitude would almost, if not entirely disappear from our unassisted sight. When we compare their spectra we find that of Sirius of the first; that of Arcturus of the second, or solar type. The small parallax found for Arcturus indicates a distance eleven million times that of the Sun from the Earth. But as the apparent magnitudes of the fixed stars vary inversely as the squares of the distances, the Sun placed at the distance of Arcturus would be diminished one hundred and twenty-one millions of millions of times. Assuming that the intrinsic brightness of the Sun and Arcturus is the same, and that the relatively greater brilliancy of Arcturus depends on its greater volume, we reach the astonishing conclusion that the bulk of Arcturus is one million times that of the Sun.

SUGGESTIONS TO AMATEURS.

LEWIS SWIFT.

Other Wonderful Nebulæ.

That mighty Nimrod of Astronomy, Sir William Herschel, hunted the sky over for the discovery of nebulæ, and found more than anyone either before or since his day. Armed with telescopes of his own construction, of far larger aperture than any previously made, he was enabled to thus achieve surpassingly greater success than had been attained by all other astronomers.

He divided the nebulæ and clusters into eight classes, a distinction still in vogue, as follows: Class (I) Bright; (II) Faint; (III) Very faint; (IV) Planetary; (V) Large. The other three sorts refer to clusters of varying degrees of resolvability. These five classes are sub-divided into round, irregular, elongated, annular and stellar nebulæ. Of class I, he discovered 288; of class II,

* Miss Clerke's System of the Stars, p. 345.

909; of class III, 984; of class V, 52; a total of 2,312 nebulæ and 197 clusters.

To the ancients, only about a half dozen visible to the naked eye were known, and the revised list of Messier reaching down to the year 1781, gives only 101 of these objects. But since Herschel's time, other observers, including his son, Sir John Herschel, have increased the number to nearly 8,000. Dreyer's New General Catalogue, published five years ago, contains the places and description of 7,840 nebulæ and clusters.

Besides the above named astronomers, D'Arrest, Auwers, Marth, both the Rosses, Stephan, Stone, Swift, Tempel, and many others have been persistent workers in this department. Of those who have discovered one hundred and over (excluding clusters) are Sir John Herschel with 1454; Swift, 900; Marth, 600; Stephan, 455; D'Arrest, 440; the Rosses, 255; Leavenworth, 253; and Stone, 100.

Though like the stars they are very unequally distributed, yet not a constellation is devoid of them, many being crowded with nebulæ. Virgo contains over 500, while the Northern Crown has only about a half-dozen.

The Milky Way, which contains nine-tenths of all the visible stars, has very few nebulæ, the most remarkable of which are the Swan or Horseshoe or Omega, right ascension $17^h\ 15^m$, declination south 16° 15′; the Trifid, R. A. $17^h\ 55^m$, Decl. — 23°; Dumbbell, R. A. $19^h\ 54^m$, Decl. north 22° 23′. The Crab nebula, R. A. $5^h\ 27^m$, Decl. + 21° 56^m, though not in the Milky Way is quite near it. This is number one of Messier's Catalogue, and its rediscovery by him on Sept. 12, 1758, while examining a comet, induced him to embody in a catalogue all nebulæ visible with his small telescope, resulting in a list of 101, though many of these are, in reality, clusters.

The Crab nebula as seen with large telescopes is in shape, a very singular object, showing radials suggestive of the claws of a crab, from whence its name. It has never been resolved into stars as has been alleged.

But of all the nebulæ visible from this latitude, none save that of Orion, are to me so interesting as the Trifid and the Swan, both of which I commend for examination to the owners of small telescopes. Radiating from the Center of the Trifid are three black channels dividing it into three nearly equal parts. In one of the rifts near its center is a star seen double by Sir William Herschel, and as triple by Sir John, but which is really quadruple. Mr. South, on July 11, 1823, with his five-foot equatorial,

measured the star so curiously situated "where three ways meet," but strangely missed the nebula which forms so striking an appendage to it. Adjoining it on the north is another nebula larger than the Trifid though much fainter, a test object, both for aperture and keenness of vision, for users of small telescopes, whom it is well to advise

"If at first you don't succeed,
Try, try again."

The Trifid was observed by Messier on June 5, 1764, and is number 20 of his Catalogue, indicated thus, M. 20. In Sir John Herschel's General Catalogue of Nebulæ, it is number 4355, and number 6514 in Dreyer's New General Catalogue. Sir William Herschel, who first observed it on July 12, 1784, thought of it as three separate nebulæ which he registered as follows: "Class V, 10, 11, 12," remarking, "Three nebulæ joined form a triangle, very faint and of great extent. In the middle is a double star." On May 26, 1786, he again viewed it and considering it then as one body, assigned it to Class IV, number 41, with this notice: "A double star with extensive nebulosity of different intensity. About the double star is a black opening resembling the nebula in Orion in miniature."

In neither catalogue does he give the position of the attached large nebula, nor does he mention it in his "remarks." Neither does Sir John in his notes on the Trifid nebula, continued down to 1833, make the slightest allusion to it though it has a pretty bright star near its center. The conclusion is, therefore, irresistible that not either of the Herschels ever saw it, and yet in both the General and the New General Catalogues it is figured as 9 of Class V. According to Auwers' synopsis of Sir William's numbers with dates of discovery and their several classes, V, 9 is given as having been discovered on May 22, 1784. The perplexing question here arises, how could he have seen this very faint nebula on May 22, 1784, and not have detected in the same field the very much brighter Trifid until May 26, 1786? This mysteriousness is my excuse for the occupation of so much space in its discussion. It was no doubt discovered in 1839 by H. L. Smith and E. P. Mason.

Some five or six years since I observed a luminous filament of the most delicate spider-line fineness stretched across its northwest cleft reminding me of one of the cables of the New York and Brooklyn suspension bridge with the difference that there was no depression from shore to shore. Owing how-

ever to electric street lights, no opportunity has since presented itself for re-observing it.

How feebly can one's imagination form, or his faltering pen convey an idea of the vastness of volume of most of the nebulæ which even small telescopes reveal as discs, when the most powerful glass can raise none on a single star! They are too vast to be conceived of or expressed in figures. Take, for instance, the one we have been considering, the Trifid nebula, and it is small in comparison with some others, and if we allow it to be as distant as the nearest stars (a reasonable supposition) and of a size that would fill the orbit of Neptune, or 5,600,000,000 miles in diameter, it would still appear with our most powerful instruments only as a very minute disk, yet with a high power it fills the entire field of view.

Although we know nothing of their distances and magnitudes, we are sure that they shine by inherent light. In our ignorance we are left to mere conjecture as to the ultimate destiny of such vast accumulations of gaseous matter, which most of them, doubtless, are. Perhaps the most reasonable supposition is that they are suns and planets in process of formation after a manner analogous to that of our own Sun and his planetary family "in the beginning."

ROCHESTER, N. Y., DEC. 21, 1893.

FIRST OBSERVATIONS OF THE SUN AND MOON.*

MARY E. BYRD.

The motion of the heavenly bodies would be far simpler if we could see in the sky one motion at a time instead of the resultant of several motions. As far as naked-eye astronomy is concerned, the Sun stands still. The motions which he seems to have are only those of the Earth transferred. Now if the Earth had but the motion of rotation, it would simply turn over and over in the same place in space and cause the Sun to appear above the eastern horizon, cross the meridian and disappear in the west. The Sun's path would be practically the same from day to day as long as the observer remained stationary. If, on the other hand, the Earth stopped rotating but moved on as usual in its orbit, keeping the same inclination to the ecliptic, the fixed observer would have the Sun above the horizon half the year, and

* Continued from January Number, p. 221.

its azimuth and altitude would change slightly from month to month. Taking things as they really are, we have in the westward movement of the Sun across the heavens, the effect mainly of the Earth's rotation, the changes in the noon altitude and in the points of rising and of setting must be referred to the orbital motion of the Earth, and the cycle of these changes should be completed in a year. Analogous to these motions of the Sun are the daily and monthly motions of the Moon. The former is, of course, apparent and due, as in the case of the Sun, to the Earth's turning on its axis; the latter presents itself in actual observation both in the eastward motion of the Moon among the stars, and in the constant shifting of the diurnal path where it intersects the horizon and crosses the meridian. This shifting is far more marked than that shown by the Sun as the period is only one-twelfth as long. It is not surprising that the monthly motion though real, presents itself under the same guise as the apparent annual motion of the Sun. For to the unaided eye, the phenomena are the same, whether the Earth goes around the Sun or the Sun around the Earth.

At whatever point we attack the problem of motion by actual observation, one thing is clear, the diurnal paths of the Sun and Moon must be located with reference to the horizon by the points of rising, southing and setting. The necessary angles in altitude and azimuth may be determined in various ways. The following involves no apparatus whatever. Take from a common almanac the time of apparent noon, and at that instant fix by permanent marks the position of the shadow. The direction of the shadow gives a rough meridian line which prolonged north and south intersects the horizon respectively in the north and south points. The celestial meridian may be described as the circle in the sky passing through these points and through the zenith. When the Sun in its daily journey comes to this circle, it is said to south, to transit or to cross the meridian; and its distance above the plane of the horizon is meridian altitude or noon altitude. In order to determine its value for a particular day, face the Sun on the meridian, decide whether it is about half the distance from the horizon to the zenith or only about a third. Then correct the 45° or 30° by dividing these angles into tenths. The observer must guard against making the distance too large near the horizon and too small at the zenith. When sunset points are to be located, stand on the meridian line facing west and stretch out the arm at right angles to the body. The line prolonged from the arm fixes approximately the west point from which the posi-

tion of the setting point is determined by measuring on the horizon the angle between these points. When this angle is large an auxiliary line aids in making a more accurate measure as, for example, if two trees or other objects are chosen so that the line passing through them cuts the horizon near the setting point. Then the distance between the intersection of the line and the point gives a constant angle which can be estimated a number of times on different days and the mean taken. From the intersection to the reference line small angles are easily measured in terms of the Sun's own diameter. These methods may, in general, be employed for sunrise and for the rising and setting of the Moon. But those who become interested in watching any heavenly body will soon be dissatisfied with mere eye estimates. In finding meridian altitudes it is some help to hold the forefingers in front of the face, one vertical and the other pointed toward the body in the sky. Pencils and rulers are better than fingers, and a better way still is to lay a ruler on the side of a wall nearly in the meridian line and measure with a protractor the angle between the edges of the wall and ruler, thus finding the zenith distance. Any one who has a gnomon can determine the zenith distance at noon by measuring the height of the vertical shaft and the length of its shadow at noon, and then computing the required angle by plane trigonometry. One student whom I know has lately made an adjustable quadrant out of a yard stick and a strip of whalebone. It is hardly comparable to Tycho Brahe's famous quadrants but its measures are better than guesses and the owner claims for it the especial merit that it is not confined to the plane of the horizon but can be used in measuring angles anywhere in the sky. The accompanying diagram gives an idea of an inexpensive instrument made of wood which a number of students have found very convenient. As nearly as was possible from a brief description, it was made like one devised by Professor W. A. Rogers of Colby University. He gave it no name but we call it the circles. A vertical shaft about five feet in height carries at the top a vertical circle fifteen inches in diameter and at the bottom a horizontal pointer placed as nearly as possible in the same plane. Both circle and pointer can be brought into any vertical plane of the horizon, as the upright shaft turns in an aperture cut in the center of the horizontal cir-

cle. The latter circle about thirty inches in diameter is graduated from 0° to 360° so that azimuth is reckoned in true astronomical fashion from the south point through the west and north points around the complete circle. The circles may be readily transformed into a gnomon by removing the upright support and vertical circle and inserting instead a shaft with a sharp tapering point of such height that the long noon shadows of summer will just reach the circumference of the horizontal circle. A large flat stone makes a good base for the instrument. One method of fixing a meridian line on the stone is to draw a chalk line north and south with the help of a compass, allowance being made for the difference between the magnetic meridian and the true meridian. If the ends of this line are cut in the stone, a permanent meridian line is secured.

The manner of using the circles is as follows. Place them so that the line between 0° and 180° lies north and south; by means of a carpenter's level, see that the vertical shaft is approximately vertical and the horizontal circle approximately level, take hold of the shaft and move it around until the plane of the vertical circle produced includes the desired object; keeping the eye still in this plane place it also in line with the pointer in the plane, move the pointer until it is in line with the object, then clamp. The readings designated on the circles by the pointers give directly the altitude and azimuth of the object. In the evening if there is neither moonlight nor twilight an assistant should hold a bulls-eye lantern behind the upper circle so that its light falls on the end of the pointer.

A number of measures are made satisfactorily at night without any instrumental help. Select two stars somewhere near the space to be measured and about the same distance above the horizon. Let the line joining the two stars be the unit of measure in which the required distance is expressed. The value of this line in degrees is easily found in two ways sufficiently accurate for naked-eye work. Find on the celestial globe the stars chosen, measure the distance between them on a narrow strip of paper and then, as all great circles in the same sphere are equal, take from the celestial equator the number of degrees corresponding to the measured space. Or, if the mean right ascensions and declinations of the stars are known for the year, the following formula will give the number of degrees between them.

$$D = \sqrt{(\Delta\delta)^2 + (\Delta\alpha)^2 \cos^2\delta}$$

where δ is the mean declination of the two stars and $\Delta\delta$ and $\Delta\alpha$

are respectively the differences in declination and right ascension of the two stars.

Suppose, for example, that the line selected is the one between α and γ Pegasi; by measurement on the globe, it equals 16°.6. By the second method the result is a little more accurate, as is shown by the following:

α Pegasi R. A. $= 22^h\ 59^m$	Decl. $= +14°\ 37'$		$14°\ 37'$
γ Pegasi $0\ 08$	$14\ 35$		$14\ 35$
$\Delta\alpha = -1\ 09 = -17°.25$	$\Delta\delta = 02' = 0°.03$	$\delta = 14\ 36$	

$$D = \sqrt{(0°.03)^2 + (-17°.25)^2 \cos^2 14°.36} = 16°.7$$

Every one who makes observations, even if they are little more than guesses, wishes to know what degree of accuracy they possess. All angular measures referring to the Sun's diurnal path are easily tested on the celestial globe. Adjust the globe so that it gives the aspect of the heavens for the time of observation. The position of the Sun corresponds to the date of the month marked on the ecliptic. Its altitude is found by laying off on a strip of paper the vertical distance between the Sun and the metal plate which represents the horizon. On the latter plate from the foot of the vertical circle measure to the nearest cardinal point, east, south or west. As described above, the two coördinates are readily expressed in degrees. In order to apply this method to the Moon, it is only necessary to know its right ascension and declination for the time of observation. Meridian altitudes of either the Sun or Moon may be checked by taking out for the day the declination given on page 6 or page 7 of *The Connecticut Almanac*. There is a typographical error in the heading of the first table, the year should be 1893. A very simple calculation furnishes the required test. As an illustration, on November 7, 1893, according to a student's observation made with the circles, the altitude of the Sun at noon was 32°. For that date the *Almanac* declination is $-16°\ 30'$. This combined with the colatitude of the place, $47°\ 41'$, gives the Sun's altitude as $31°\ 11'$. *The Connecticut Almanac* is computed for New Haven but no interpolation is necessary in case of the Sun even for a place whose longitude differs by several hours.

No problems connected with apparent motion are more interesting than those which deal with the rate of this motion. At the instant when the Sun is on the meridian, its path is parallel to the horizon. An hour before and an hour after meridian passage, imagine vertical circles passed through the Sun and prolonged to

the horizon. Since the downward curvature of the path is small between these two positions, the arc intercepted on the horizon gives approximately the number of degrees passed over by the Sun in two hours. Making use of this method for the Moon, five students during the past October observing independently with the circles, obtained hourly rates for the Moon varying from 13¼° to 14¼°.

Another method applicable to the Moon is best described by giving an outline of an actual observation. The student stood on one of the Observatory steps from which point the Moon was seen toward the southeast, a short distance above a white birch tree. In the sky not far away was the square of Pegasus. The line between α and γ was taken as the measuring line and the Moon's distance above the tree estimated to be a certain part of this unit. An hour later the student looked again from the same position, the same part of the measuring line was laid off above the tree and the Moon put back in imagination in the place it first occupied and, finally, the interval between this imaginary Moon and the real Moon in the sky was estimated in terms of the measuring unit. This way of obtaining the apparent hourly rate of the Moon's motion involves, of course, the error of assuming the motion to be in a great circle; for so short a time, however, the error is small compared with the probable error of observation.

No mention has thus far been made of observations for finding the motion of the Moon among the stars, nor for determining its latitude and longitude, right ascension and declination. Any student, however, who has put into practice a few of the foregoing suggestions will have no difficulty in making such applications and modifications as these problems demand. A few hours of genuine study of the heavenly bodies is better than much reading. The royal road of astronomy does not lie in a library, it is out of doors under the open sky.

CONSTELLATION STUDY.

WINSLOW UPTON.

IV.

The preceding articles of this series have discussed the general plan of constellation study which is recommended. It remains to take up the several constellations in turn and give suggestions

for learning their leading features, as far as this can be done on a printed page. For at this point it is necessary to pass from a written description to the sky itself, and use such aids as star atlases may supply.

A word here regarding star atlases will not be out of place, for a good star atlas is indispensable to a thorough study of the constellations, and almost as necessary for the merest outline study of them. A number of excellent atlases can be purchased, each having special advantages, and some better adapted for one purpose than another. Individual preferences of course vary, and the opinions of the writer accordingly may not agree with those of others. Among the atlases available for the student the following are standard works: Argelander's Uranometria Nova and Heis' Atlas Cœlestis. These are the authoritative charts of the astronomer and thoroughly reliable. The former is nearly an ideal chart for the student who wishes to carry the study to some detail, or to have a standard atlas for reference, as it gives all the stars visible to the naked eye, and also contains the boundaries of the constellation areas and the outlines of the historical figures with sufficient distinctness for use, but not with undue prominence. Klein's star atlas and Proctor's larger atlas give more stars and the plates are therefore somewhat crowded, which is at first an embarrassment. The historical figures are omitted in these atlases. For a more general study less comprehensive works such as Proctor's Half Hours with the Stars, Burritt's Atlas to his Geography of the Heavens, Young's Uranography, are to be recommended, but the student is likely to outgrow them if he is persistent in the study. Burritt's Atlas has the advantage of large pages, but the historical figures are rather too prominent for their importance in the science of today. Besides atlases, the charts known as planispheres which can be set for any given hour are quite useful. Among those now in the market is Poole Bros.' Celestial Planisphere, which is very serviceable. It gives the brighter stars with the leading clusters and nebulæ, and like Young's Uranography has guiding lines which are a help in tracing the configurations. The constellation boundaries are given but not the historical figures, though the latter are given in the accompanying Handbook. The chart which is published in this number of POPULAR ASTRONOMY is a reproduction of a portion of Poole's Planisphere, and may be referred to in reading the remainder of this article.

In taking up the constellations in turn let us recall the classification adopted in the earlier articles of this series. We are to

imagine the heavens divided into four lune-shaped areas, the boundaries of which are the equinoctial and solstitial colures. Then for convenience we are to take from each of these four sections the part in the vicinity of the pole and make a circumpolar map. Our five divisions are the circumpolar map and the four divisions thus decapitated. Were we to discuss all the constellations of the southern sky we should need a circumpolar map around the south pole corresponding with that around the north pole. We will first notice the constellations around the north pole and then those of the four sections, according to the list given in the second article of this series. Before doing this we should note how the four divisions of the sky are placed at the time of observation. To do this we should trace the line of the equinoctial colure and imagine the solstitial colure drawn at right angles to it, intersecting it at the pole star. If it is in the evening of some night in February, the solstitial colure will run not far east or west of the meridian, and the first division of the sky will lie west of it and the second east of it. The third and fourth divisions are below the horizon except near the pole. If the observer faces the north for the circumpolar groups the first division lies above the pole west of the meridian (or more strictly west of the solstitial colure, which will only momentarily coincide with the meridian in the diurnal motion of the heavens), the second division lies above the pole east of this line, the third division is below the second and the fourth below the first. The bowl of the "Dipper" is in the second and its handle in the third division.

Constellations North of the Zenith, as seen in Northern Latitudes.

Cassiopeia. The line drawn from δ Ursæ Majoris to the Pole Star, if prolonged an equal distance passes through β Cassiopeiæ. δ Ursæ Majoris is the star marking the junction of the handle and bowl of the Dipper. The area called Cassiopeia is on the opposite side of the pole from the part of Ursa Major in which is the handle of the Dipper. The characteristic figure of Cassiopeia is a quadrilateral and two additional stars the line connecting which is nearly parallel with one of the sides of the quadrilateral. The figure made is somewhat like a chair, the four stars of the quadrilateral forming the body and the two other stars the back. There is a third star in the prolongation of the line representing the back of the chair which makes the chair a high-backed chair as some see it. The stars are conspicuous,

with the exception of the one lettered κ where the knee of a person would come when sitting in the chair. A person thus sitting would face Draco. While this group is called Cassiopeia's Chair, the ancients did not represent the queen sitting in the chair; the stars which make the shape of the chair are a part of the figure of the royal lady, whose feet are towards the pole. The quadrilateral of stars is in the upper part of the body and the head is represented in the sky by a few faint stars just south of the quadrilateral. There are many faint stars visible to the naked eye besides those named, and the Milky Way passes through the quadrilateral of stars.

Camelopardalis. This name was given by Hevelius in the 17th century to the large area immediately following Cassiopeia, as the heavens rotate. The name is sometimes written Camelopardalus or Camelus. There are no stars in this area brighter than the fourth magnitude. The head of the giraffe is drawn near the pole star between it and the extremity of the tail of Draco. It is possible to trace a winding line of faint stars near the boundaries of the area, as shown on the chart of stars published in this number of POPULAR ASTRONOMY, but it requires a clear sky to do this.

Ursa Major. This large area contains the conspicuous stars of the Dipper and certain other stars around which the outlines of a bear may be drawn. The handle of the Dipper forms the tail of the bear and is out of all proportion to the size of that appendage in nature. Heis in his Atlas draws the diminutive tail of the terrestrial bear in addition to the gorgeous attachment required by the stars. The bowl of the Dipper is in the body of the animal. The head is marked by a group of small stars which may be found by prolonging the line connecting the upper stars of the bowl, α and δ. Three of the paws are marked each by a pair of stars which is a curious feature of this constellation. They may be found in this way: Prolong towards the south, that is away from the pole, the two pairs of stars forming the sides of the bowl of the Dipper, α, β and δ, γ. These lines converge to a bright star lettered ψ. This star is at the vertex of a triangle whose other vertices are two of the pairs, the two at which the hind paws of the bear are drawn. They are lettered ν, ξ and λ, μ respectively and are represented on the chart, which shows another way to find them. The third pair, lettered ι, κ and marking the position of one of the four paws may be readily found by prolonging the line δ, β of the Dipper, passing through the bright star θ on the way. There is a fourth pair of stars

which might have represented the other fore paw had not the astronomer Hevelius in giving the name Lynx to a vacant space between the groups Ursa Major and Auriga of Ptolemy's list included them in the new constellation. The Dipper and the three pairs of stars above named are the characteristic features of the constellation and with the group constituting the head of the bear show the extent of space covered by it.

Ursa Minor. The seven leading stars of this constellation form the "Little Dipper" which can be readily traced by starting with the pole star, which is at the end of the handle, and following the rather faint curved line of stars to the four forming the bowl of the dipper. This is illustrated on the chart. If there is any difficulty in finding this figure, another way is to notice the line connecting the pole star with the end of the handle of the Great Dipper, the star η Ursæ Majoris. The two stars β and γ of Ursæ Minoris lie a little out of this line not quite half-way from the pole star. When these are found the construction of the rest of the figure from the four faint stars between these two stars and the pole star is not difficult. As in the case of the Great Bear, the handle of the Dipper is the tail of the Little Bear, and the bowl part of its body.

Draco. This winding constellation is a good example of the snake-like figures which can be readily formed among the stars, and which are almost the only configurations bearing any resemblance to the objects suggested by their names. A quadrilateral of stars forms the head of the figure. Its position is close to the solstitial colure,—the arc which is nearest the winter solstice, or the XVIII hour circle. In February evenings this is the part of the colure which extends from the pole towards the north horizon. The head of Draco is 25° from the pole, and therefore may not be readily detected unless the sky is clear near the horizon. When found, the winding line of stars marked on the chart can be readily traced, passing between the two dippers. It is sometimes easier to begin at the tail of the dragon and trace the line towards the head. In this case the star which marks the intersection of the line drawn from the "pointers" of the Great Dipper to the pole star with the dragon, lettered λ, is a good one to begin with. The star α Draconis, which is nearly in the line connecting the pole star with the end of the handle of the Great Dipper, is the star which was the nearest bright star to the pole at the time of the building of the great pyramid. In tracing the figure of the dragon it will be noticed that at the turning points where folds of the dragon are usually drawn there are groups of small stars.

Cepheus. This constellation lies between the head of Draco and the constellation Cassiopeia. A large part of its area is devoid of prominent stars. Its characteristic figures are a group of stars at the southernmost limit of the area, where the head of the king is drawn, and a broken line of three third magnitude stars further north near the center of the area. The former group consists of a variable star, one of the fourth magnitude, and one of the fifth magnitude, forming a triangle with several very faint stars adjacent. The easternmost of the triangle (at the left when the group is seen below the pole), lettered δ, is the variable star and one of the best known in the sky. It fluctuates between the fourth magnitude and the fifth every five days. The broken line of stars referred to embraces the only conspicuous stars in the constellation. The two southernmost form a line with the pole star, very much as the pointers of the Dipper, and the third makes an obtuse angle of about 130° with this line.

These six constellations occupy the greater part of the area within 40° of the northern pole of the sky. Three other constellations, Perseus, Auriga, and Lynx have a large part of their area within this circumpolar region, but their most conspicuous stars are farther south, and they will be treated with the constellations which culminate south of the zenith in northern latitudes.

The following table contains the approximate positions of the leading stars in each constellation. It is given for use in charting the stars, as suggested in the third article of this series.

APPROXIMATE POSITIONS OF THE LEADING STARS IN THE CIRCUMPOLAR CONSTELLATIONS.

Name.	Magnitude.	Right Ascension. h m	Declination. ° ′
CASSIOPEIA.			
β	2.4	0 4	58 36
κ	4.2	0 27	62 23
α	2.2	0 35	56 0
γ	2.3	0 51	60 10
δ	2.8	1 19	59 37
ε	3.6	1 47	63 11
CAMELOPARDALIS. (No Bright Stars.)			
URSA MAJOR.			
o	3.4	8 22	61 3
ι	3.2	8 52	48 26
κ	3.7	8 57	47 33
η	3.2	9 26	52 8
λ	3.6	10 11	43 25
μ	3.1	10 16	42 0
β	2.6	10 56	56 55
α	2.0	10 58	62 18

URSA MAJOR. Cont.

Name.	Magnitude.	Right Ascension.	Declination.
ψ	3.1	11 4	45 3
ξ	4.8	11 13	32 6
ν	3.8	11 13	33 39
γ	2.6	11 49	54 15
δ	3.4	12 10	57 35
ε	1.8	12 49	56 30
ζ	2.6	13 20	55 26
η	2.0	13 44	49 49

URSA MINOR.

α	2.2	1 17	88 46
β	2.1	14 51	74 34
γ	3.2	15 21	72 11
ζ	4.5	15 48	78 6
η	5.0	16 20	75 59
ε	4.5	16 56	82 12
δ	4.3	18 7	86 37

DRACO.

λ	4.1	11 26	69 54
κ	3.8	12 29	70 20
α	3.6	14 2	64 51
ι	3.4	15 23	59 19
θ	4.2	16 0	58 49
η	2.8	16 23	61 44
ζ	3.3	17 8	65 51
β	3.0	17 28	52 22
ν	4.8	17 30	55 14
ψ	4.8	17 45	72 12
ξ	3.9	17 52	56 54
γ	2.4	17 54	51 30
φ	4.2	18 22	71 17
χ	3.7	18 23	72 42
δ	3.2	19 12	67 29
ε	3.9	19 48	70 1

CEPHEUS.

α	2.6	21 16	62 10
β	3.4	21 27	70 1
δ	3.7 — 4.9	22 25	57 54
γ	3.4	23 35	77 4

VARIABLE STARS. IV.

J. A. PARKHURST.

The worst foe to accuracy in variable star work is a preconceived notion of what the star is going to do. Too much emphasis cannot be placed on the caution against this source of error. The work should be approached in a "judicial frame of mind" and the observer must train himself to record just what he sees, nothing more or less. With this end in view it is better not to make the reductions explained in the January number

till the star has certainly passed a maximum or minimum, nor to learn from the ephemeris when the maximum or minimum ought to occur, except barely enough to be prepared for observation. For this reason POPULAR ASTRONOMY gives the times of minima of the Algol stars only to the nearest hour, though for most of them the predictions can be made very much closer.

The principal facts in regard to the period of variables are given concisely in what are termed their elements. These consist of 1st, the epoch; 2d, the length of period. The time of the first well determined maximum is generally taken as the epoch, and if the period is regular the time of any other maximum can be found by multiplying the length of period by the number of periods elapsed since the epoch and adding the product to the time of the epoch. For example Chandler's elements for 107 T Cassiopeiæ are—

$$1871 \text{ March } 31 + 445.0 \text{ E},$$

in which E represents the number of periods elapsed since the epoch.

It is not always possible to represent a star's variation by so simple an expression as the above. In some cases a star's period will gradually shorten till it is about five-sixths the usual length, then lengthen till it is as much longer than the average, thus showing that there is a secondary cause at work with the principal one, their varying combination giving different lengths of period. This can often be represented in the elements by what is called a "sine term." For example the elements of 5237 R Boötis are—

$$1858 \text{ June } 8 + 223.4 \text{ E} + 10 \sin (10^\circ \text{ E} + 80^\circ).$$

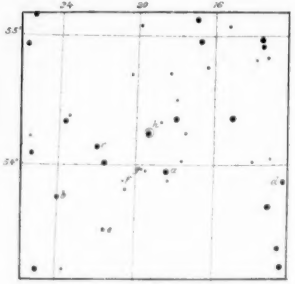
As the value of the sine varies from + 1 to — 1 the last term can have values from + 10 to — 10 and the period will vary from 233.4 to 213.4 days.

There is a progressive lengthening or shortening in the case of some variables which can be represented by terms containing the second or third power of E while other stars defy any number of terms to follow their idiosyncrasies.

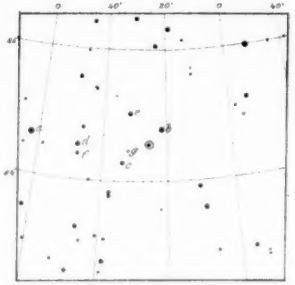
IDENTIFYING THE VARIABLE.

If the observer has a telescope provided with finding circles he will have no difficulty in picking up the fields charted in this and preceding numbers, and with attention he will be able to identify the variables. If he has no finding circles the operation will not be so easy and some suggestions may be helpful. First

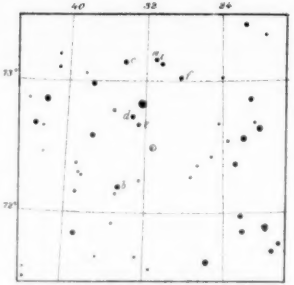
CIRCUMPOLAR VARIABLE STARS OF LONG PERIOD.



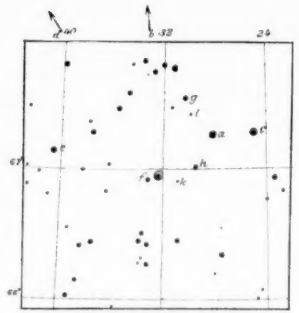
5157 *S Bootis.*
R.A. $14^h\,19^m.5$ DEC. $+54°16'$.



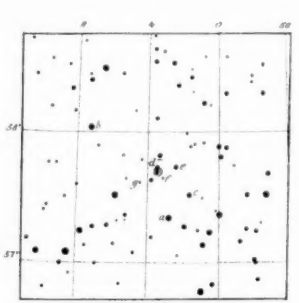
5190 *R Camelopardi.*
R.A. $14^h\,25^m.1$ DEC. $+84°17'$.



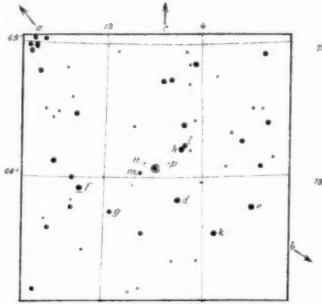
5948 *R Ursæ Minoris.*
R.A. $16^h\,31^m.3$ DEC. $+72°29'$.



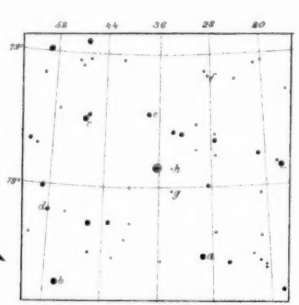
5955 *R Draconis.*
R.A. $16^h\,32^m.4$ DEC. $+66°58'$.



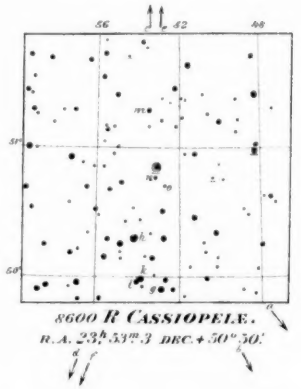
7220 *S Cygni.*
R.A. $20^h\,3^m.4$ DEC. $+37°42'$.



7609 *T Cephei.*
R.A. $21^h\,8^m.2$ DEC. $+68°5'$.



7779 *S Cephei.*
R.A. $21^h\,36^m.5$ DEC. $+78°10'$.



8600 *R Cassiopeiæ.*
R.A. $23^h\,53^m.3$ DEC. $+50°50'$.

make an enlarged copy of the chart for each variable, locating carefully the stars charted and also the comparison stars from the lists in the January and February numbers, down to a magnitude a little below the limit of vision of the telescope used. Locate the variable on the star atlas by means of its given Right Ascension and Declination, and note its relation to the nearest naked-eye stars which can be identified. In most cases the telescope can be pointed at the sky within a degree or so of the proper direction. A little careful sweeping will now suffice to find and recognize some part of chart, and so on to the variable, *provided* that three facts are known: 1st. How faint stars one can expect to see. The table given in the October number, page 91 will settle that point. 2d. Which is north in the sky and on the chart. 3d. How large a portion of the chart will be included in the field of view. To settle this last point it will be well to draw a circle on the chart with the variable as a center and the breadth of the field of view as a diameter. This will show just what can be seen when the telescope is correctly pointed on the variable. Most of the difficulty beginners find in locating variables will come from neglecting some of these three points, but by taking them into account a little practice will enable the observer to locate the variables readily without finding circles.

The list of comparison stars for the variables charted opposite page 216 in the January number, is on page 237.

The plate accompanying this article is the companion to that published in the January number and is generously contributed by Professor E. C. Pickering of Harvard College Observatory.

The plate and the list of comparison stars are taken from Pickering's "Variable Stars of Long Period."

The principal facts in regard to the variables are given in the following table, taken from Chandler's "Second Catalogue of Variable Stars."

Star No.	Name	Place for 1900.0 R. A. h m s	Decl. ° ′	Redness	Magnitude Max.	Magnitude Min.	Period days.
5157	S Boötis	14 19 32	+ 54 15.9	2.8	7.7 — 8.5	12.5 — 13.2	274.0
5190	R Camelopardalis	14 25 6	+ 84 17.1	2.1	7.2 — 8.6	11.8 — 13.5	269.5
5948	R Ursæ Minoris	16 31 18	+ 72 28	3.2	8.6 — 9.0	10.5	Irreg.
5955	R Draconis	16 32 23	+ 66 57.8	2.0	6.5 — 8.7	12 — 13	245.6
7220	S Cygni	20 3 24	+ 57 41.9	5.1	8.8 — 11.3	< 14.5	322.8
7609	T Cephei	21 8 13	+ 68 5.0	6.3	5.2 — 6.8	9.5 — 9.9	383.3
7779	S Cephei	21 36 28	+ 78 10.3	9.1	7.4 — 9.2	11.5	484
8600	R Cassiopeiæ	23 53 19	+ 50 49.9	6.5	4.8 — 7.0	9.7 — 12	429.0

The period of S Boötis is undergoing a progressive shortening; that of R Camelopardalis has irregularities whose law is not yet

established. The periods of S Cephei and R Cassiopeiæ alternately lengthen and shorten.

Most of the variables charted in the January and February numbers will be visible in February with a two-inch telescope. The brightest of the list will probably be numbers 8600, 5955, 5190, 5157, 107, 4511, 793, 814, 1855. Three inches aperture will show 7609, and 5157; five inches will show 7779, 4557 and 3825, while six inches or more will be required to see 7220, 2478 and 432.

MARENGO OBSERVATORY,
Marengo, Ill. 1894, Jan. 8.

DOES THE LUMINIFEROUS ETHER SERVE AS A MEDIUM FOR THE TRANSMISSION OF THE FORCE OF GRAVITATION?

DE VOLSON WOOD.

In the January number of POPULAR ASTRONOMY, page 199, I find the statement: "This ether apparently does not gravitate, but it may, notwithstanding, be the medium by which the influence of gravitation, as well as of light, heat, and electricity, is propagated." The suggestion that the luminiferous ether transmits the force of gravity, is comparatively frequent; but according to recognized laws, it is physically impossible for the same medium to transmit both light and the force of gravity. The reasoning is simple. Including the effect due to the compression produced by a wave, the velocity with which a wave is transmitted in an elastic medium is

$$v = \sqrt{\frac{\gamma E}{D}}$$

where E is the measure of the elasticity and D the density—or mass in unity of volume—and γ the ratio of the specific heat at constant pressure to that at constant volume whose value is 1.4 nearly. In my article on the luminiferous ether in the London *Philosophical Magazine* for November, 1885,* I determined that, according to the data at hand,

$$E = \frac{4}{10^5} \text{ and } D = \frac{2}{35 \times 10^{24}}$$

per cubic foot. These values give

* Republished in Van Nostrand's Science Series, No. 85.

$$v = 187500 \text{ miles}$$

per second. The observed value is

$$v = 186300 \text{ miles per second.}$$

Considering the fact that the value of $\gamma = 1.4$ is entirely arbitrary in regard to the ether, the result rather confirms the analysis. The particular point we desire to make is this—that a medium of fixed elasticity and density can transmit a wave with only one velocity, and that if it does transmit a wave with any other velocity either the elasticity or density, or both, must be changed. It is believed that the ether is practically uniform in regard to elasticity and density throughout space; and this idea is confirmed by the analysis in the article above referred to. Such being the case, the velocity of a wave in the ether will not differ very largely from 186300 miles per second; certainly no cause is known why it should be twice or three times that value. But La Place found that if the force of gravitation, if propagated by an elastic medium, must have a velocity exceeding a hundred millions times that of light (*Mech. Celeste*, B. X, ch. 8). It is then physically impossible for gravity to be propagated by the luminiferous ether. If gravity is propagated by an ether, it must be one peculiar to itself, which we may call the "gravitation ether" in which the ratio of E to D as far transcends that for the luminiferous ether, as that ratio for the ether transcends its value for atmospheric air.

If the luminiferous ether be molecular and subject to the force of gravitation, it will not be drawn to the centres of force so as to leave void spaces, for as I showed in my article the force of repulsion between the particles will so counteract gravitation as to leave it of practically uniform tension throughout space.

SHOOTING STARS.

How to Observe Them and What they Teach Us.

W. F. DENNING.

VI. The August Perseids.

Having touched upon some of the observational features of shooting stars it is now proposed to give a little space to the description of three of the leading showers, namely, the Perseids

of August and the Leonids and Andromedes of November. The former of these will form the subject of the present paper and though the Perseid system cannot, it is true, boast of such abundant and brilliant displays as the Leonids and Andromedes it compensates for this in its more frequent appearance. Every year as the anniversary of St. Lawrence (August 10) comes round the Perseids return more or less plentifully and the observer who attentively watches them is always amply repaid for his trouble. No doubt variations affect the visible strength of the stream from year to year, but it is invariably sufficiently pronounced to merit observation and sometimes so rich and striking as to attract popular notice.

The Perseids form one of the oldest meteor groups of which we are cognizant, for its observed returns apparently date back to the ninth century when several displays were historically recorded as having occurred in the latter part of July. Quetelet's catalogue contains seven instances of the shower's apparition between A. D. 811 and 841, but in the ensuing centuries it seems to have rarely met with the recognition it deserved and it was not till the latter part of the 18th century that it received special notice. It then began to be more systematically observed though its features in detail still awaited study. The earlier observations appear to have simply consisted in noting that on about August 10th meteors were much more numerous than usual, and occasionally something was added as to their general directions relatively to the points of the compass. That the bulk of the meteors exhibited radiation from a centre in Perseus does not appear to have been clearly apprehended until a third of the present century had passed away and more serious attention was accorded to the subject of meteors. After the great display of Leonids in 1833 interest in these phenomena was however much intensified and the facts showed them to possess an important significance. The necessity of recording the apparent paths of individual meteors and other features of their appearance was then realized, and Heis, Herrick, Schmidt and others became the successful pioneers in this complicated field of astronomy.

One of the earliest observers to determine the Perseid radiant was G. C. Schaeffer of New York who in 1837 and 1838 placed it at $55° + 60°$. In late years it was more accurately fixed by Greg, Herschel, Twining and others at $45° + 57°$. Schiaparelli's discovery in about 1866 that the orbit of the Perseids and of Tuttle's Comet (III 1862) presented an agreement so close that

their physical identity was to be inferred, gave another stimulus to this department and greatly encouraged the efforts of observers.

The Perseids were long known to possess a very durable activity, with maximum on about August 10, and Le Verrier pointed out that the radiant point ought to become displaced in position on succeeding evenings. This was not however detected until 1877 though Greg found the radiant an elongated one extending from Perseus to Cassiopeia. A numerous series of observations at Bristol in 1877 clearly proved that the radiant had a motion to the eastward, a fact which was amply corroborated in subsequent years when the rate and direction of this motion were determined with greater precision. On July 19 the point of radiation is at $19° + 51°$, whereas on August 10 it is at $45° + 57°$ and its R.A. increases at the rate of little more than 1° daily. The following diagram will exhibit the approximate path of the radiant between July 19 and August 17.

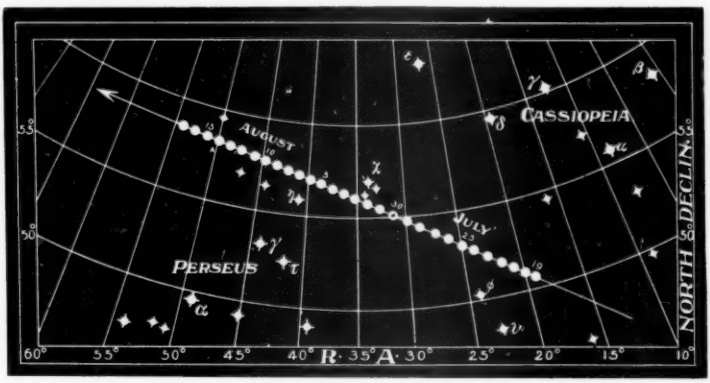


FIG. 5. PATH OF THE PERSEID RADIANT JULY 19 TO AUGUST 17.

The shower is probably visible before July 19 and after August 17 but for present purposes these limiting dates are adopted as the observations indicating a still longer duration are perhaps too scanty to be conclusive.

There are a considerable number of minor showers in simultaneous operation with the Perseids and they have served to introduce complications and to give the Perseid radiant a diffuse character not really belonging to it. When the meteors in this region are severally apportioned to their proper centres the focus

of the Perseids often comes out with remarkable definiteness. There are certainly more than 100 distinct meteor streams in active play on about August 10 (say between August 5 and 15) and the radiant positions of many of the more prominent of these have been ascertained in a satisfactory manner. In the following table 72 of them are enumerated, but it must be understood that they comprise a proportion only of the aggregate of co-Perseid showers and that in some cases the positions may require correction as they represent extremely weak showers:

METEORIC RADIANTS VISIBLE AUGUST 5-15.

°	°	°	°	°	°	°	°
3	+ 27	49	+ 30	104	+ 79	304	− 13
4	− 2	54	+ 71	104	+ 34	310	+ 77
7	+ 11	55	+ 84	134	+ 77	311	+ 62
8	+ 53	61	+ 39	186	+ 74	312	+ 15
9	+ 34	61	+ 48	213	+ 53	315	+ 48
19	+ 29	61	+ 60	215	+ 76	320	+ 31
20	+ 58	63	+ 22	242	+ 49	320	+ 11
23	+ 36	70	+ 51	250	+ 55	320	− 12
25	+ 42	70	+ 65	255	+ 37	331	+ 49
28	+ 72	74	+ 41	264	+ 62	332	+ 71
30	+ 36	76	+ 74	270	+ 20	333	+ 10
31	+ 49	77	+ 32	271	+ 48	333	+ 27
32	+ 18	78	+ 57	284	− 12	334	+ 57
38	− 13	87	+ 34	291	+ 70	340	− 13
40	+ 28	87	+ 15	292	+ 53	343	+ 12
41	+ 23	92	+ 57	296	± 0	347	± 0
43	+ 39	96	+ 71	296	+ 86	350	+ 51
48	+ 44	98	+ 43	302	+ 24	351	+ 38

It will be noticed that nearly all of these showers are in the northern hemisphere. There are undoubtedly a great number of others in the southern hemisphere but the quest of meteor radiants has never been adequately pursued in this part of the firmament. In fact the southern heavens may be said to offer a rich and comparatively unexplored field and it is hoped the day is not far distant when some thoroughly competent observer will make it the theatre of his labors.

The following diagram may be useful as indicating the places of 34 radiants in the same general region as the Perseids between Aug. 5—15. No doubt there are many additional ones, but these are probably the best. It will be interesting to find whether these subordinate systems continue active in future years and whether they offer a regular annual display like the Perseids.

With regard to the hourly number of meteors visible at the August epoch this varies in different years but at the end of July, early in August, and between August 13 and 25, a single observer may generally count 20 an hour. From observations at Bristol some years ago the writer constructed the diagram annexed

which shows the horary rate of all meteors and of Perseids between July 25 and August 19. It will be seen on inspection that the numbers increase and decline very suddenly near the date of the maximum. At the end of July there is a marked rise in the total number of meteors which is not due to the Perseids but to a specially active shower of Aquarids revealed by observations in 1878.

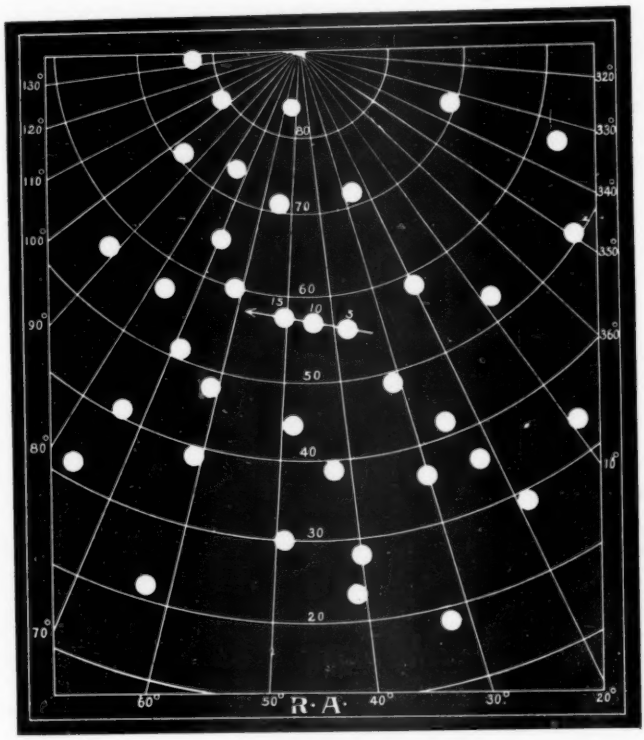


Fig. 6. Perseid and Contemporary Radiants in Same Region Between August 5 and 15.

From carefully observed tracks the radiant may always be determined within a probable error of 2 degrees. To show how closely the positions obtained by different observers may agree we quote the following results obtained in 1879 and 1880, at the time of the Perseid maxima:—

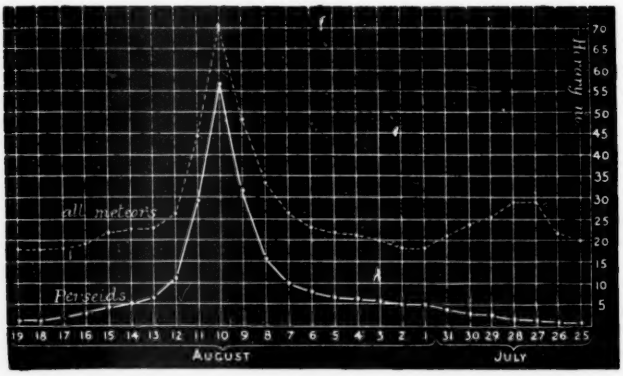


FIG. 7. DIAGRAM EXHIBITING HORARY NUMBERS OF ALL METEORS AND PERSEIDS. JULY 25–AUG. 19.

Observer.	1879 Aug. Radiant.		1880 Aug. Radiant.	
	°	°	°	°
G. L. Tupman	45	+ 51	44	+ 51
H. Corder	45	+ 57	45	+ 58
E. F. Sawyer	44½	+ 57	44¾	+ 51¼
W. F. Denning	46	+ 58	44	+ 56

There are some other circumstances in connection with the Perseids which we might have noticed but the objeet has merely been to outline some of the facts and to give a few details which may invite comparisons by future observers. It is by fair comparison and criticism that the truth is evolved and continued observation, while affording the means of detecting errors, also furnishes the corroboration often necessary to render doubtful features certain. We hope that many of the future spectators of this fine shower will do so with a keen regard to details so that all its traits of appearance may be fully elucidated. That the display will always command appreciative observers cannot be doubted for a moment, for apart from the abundance of its meteors and their occasional splendor, the shower comes at the most attractive season of the year when the nights are getting suitably dark and the observer can remain out of doors for hours together without any of the inconveniences attached to the winter season.

THE NEED OF A FREE ASTRONOMICAL OBSERVATORY.

FLORENCE ARMITAGE.

Why among all the noble achievements for the benefit of the masses in this enlightened age, have not the promoters of education and science established a *free* Observatory for the study and advancement of that most grand, elevating and enlightening science, Astronomy?

As vice is mostly due to ignorance and narrow-mindedness, would it not be achieving a great purpose if the ignorant be aroused to the fact that this Earth is but one body, and that a very small one of many, flying through space; and that our short life here is not given us to live for the gratification of worldly pleasures but for perfecting the mind in so far as we are able, and that the more highly educated the more capable the mind of realizing what boundless omnipotence rules the universe including all the starry host?

What can teach this better than Astronomy?

Some scoff at religion and demand *proof* of the existence of supreme power. What can illustrate perfection of might as the wonderful laws which govern the universe? Not night or day, weeks, months, years or centuries fail. Supremely and silently all was and is. What can more grandly illustrate the existence of supreme perfection and unchangeableness?

We *can* and *must* have a building in the city of New York where telescopes may be erected, the people assembled and those of learning teach the elements of Astronomy.

Consider what wonders might be revealed if many assisted in unraveling the mysteries of time and space.

Money should be raised to perfect this plan and it rests with scientists and the noble minded to do this great work.

By the co-operation of the readers of POPULAR ASTRONOMY, subscriptions might be started immediately for a site, buildings and instruments.

John Tyndall, the eminent physicist, died at Haslemere, England, Dec. 4, 1893. Few men of science have been more widely or favorably known than he. He was born Aug. 21, 1820, at Leighlin Bridge near Carlow, Ireland. In January–February *Physical Review* will be found a good brief note giving a sketch of Professor Tyndall's life and work. A fine small portrait makes the frontispiece of the same number.

PLANET NOTES FOR MARCH.

H. C. WILSON.

Mercury during March will be passing between the earth and the Sun, as may be seen from the diagram in our last number, page 228. For the first two or three days the planet will be visible in the evening just after sunset. In order to see it one must look toward the west, just a little above the horizon. On March 14, 2^h 18^m A. M., Mercury will be in conjunction with the Sun, and after that time it will be morning planet.

Venus will be morning star and rapidly come out from the rays of the Sun. She will increase rapidly in brilliancy so that none can mistake her, greatest brilliancy being attained on the 22nd of March. Venus will be in conjunction with the waning moon, 12° 28′ north, March 4 at 9^h 39^m P. M. Central time.

Mars rises about 4 o'clock in the morning and is at such a southern declination that there will be little opportunity for observation of this planet in northern latitudes during March. It is in the constellation Sagittarius and moving eastward. Mars will be in conjunction with the Moon, 4° 44′ north, March 1 at 11^h 29^m P. M. and again March 30 at 11^h 38^m P. M.

Jupiter will be in good position for observation in the early evening. The position of this planet among the stars is shown upon the Poole Bros.' map at the end of this number. Jupiter will be in conjunction with the Moon, 4° 40′ south, March 11 at 2^h 40^m P. M.

Saturn rises in the evening and will be in good position for observation after midnight. For the position of this planet in the constellation Virgo see the chart in our last number. Saturn will be in conjunction with the Moon, 4° 24′, north, March 23 at 3^h 01^m A. M.

Uranus is in the constellation Libra, southeast from Saturn (see chart page 230), and may be observed after midnight. Uranus will be in conjunction with the Moon, 3° 39′ north, at 6^h 12^m P. M., March 24.

Neptune will be in good position for observation during the early evening in March. The position of this planet in Taurus is shown on Poole Bros.' map at the end of this number. We are sorry that, by the process used in reproducing the photograph of the Neptune region (Plate XI in our last number), more than two-thirds of the stars shown in the photograph were lost, thus destroying to a large extent its value to the amateur who might use it as a means of finding the planet.

The asteroid *Juno* is in the constellation Libra about 5° northeast of the star β. It is making the turn of the loop in its apparent path and after the middle of the month will move westward.

Planet Tables for March.

[The times given are local time for Northfield. To obtain Standard Times for Places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Mar. 5.....	23 51.8	+ 2 33	6 44 A. M.	12 57.6 P. M.	7 11 P. M.
15.....	23 27.0	+ 0 02	5 50 "	11 53.7 A. M.	5 57 "
25.....	23 06.7	− 4 33	5 09 "	10 54.1 "	4 40 "

VENUS.

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Mar. 5	21 20.5	− 7 36	4 54 A. M.	10 27.0 A. M.	4 00 P. M.
15	21 25.0	− 8 59	4 24 "	9 52.0 "	3 20 "
25	21 42.5	− 9 23	4 04 "	9 30.3 "	2 56 "

MARS.

Mar. 5	19 00.6	− 23 16	3 42 A. M.	8 07.5 A. M.	12 33 P. M.
15	19 31.0	− 22 32	5 31 "	7 58.5 "	12 26 "
25	20 01.0	− 21 27	3 16 "	7 49.1 "	12 22 "

JUPITER.

Mar. 5	3 32.4	+ 18 25	9 18 A. M.	4 37.8 P. M.	11 58 P. M.
15	3 38.7	+ 18 49	8 43 "	4 04.8 "	11 27 "
25	3 45.8	+ 19 15	8 09 "	3 32.6 "	10 57 "

SATURN.

Mar. 5	13 34.1	− 6 54	9 02 P. M.	2 37.8 A. M.	8 14 A. M.
15	13 32.0	− 6 40	8 19 "	1 56.3 "	7 33 "
25	13 29.5	− 6 24	7 36 "	1 14.6 "	6 53 "

URANUS.

Mar. 5	14 51.5	− 16 01	10 57 P. M.	3 55.0 A. M.	8 53 A. M.
15	14 50.8	− 15 58	10 16 "	3 14.9 "	8 13 "
25	14 49.8	− 15 53	9 36 "	2 34.6 "	7 33 "

NEPTUNE.

Mar. 5	4 37.8	+ 20 35	10 13 A. M.	5 43.0 P. M.	1 13 A. M.
15	4 38.2	+ 20 37	9 34 "	5 04.1 "	12 35 "
25	4 38.9	+ 20 39	8 55 "	4 25.5 "	11 56 P. M.

THE SUN.

Mar. 5	23 05.0	− 5 51	6 31 A. M.	12 11.5 P. M.	5 52 P. M.
15	23 42.2	− 1 55	6 13 "	12 08.9 "	6 05 "
25	0 18.7	+ 2 01	5 55 "	12 05.9 "	6 17 "

Phases and Aspects of the Moon.

Central Time.

	d	h m	
Apogee	Mar. 1	10 06	A. M.
New Moon	" 7	8 18	A. M.
First Quarter	" 14	12 28	P. M.
Perigee	" 16	11 18	P. M.
Full Moon	" 21	8 11	A. M.
Last Quarter	" 29	2 28	A. M.
Apogee	" 29	6 42	A. M.

Approximate Central Standard Times when the Great Red Spot will cross the Central Meridian of Jupiter.

	h m			h m			h m
Mar. 1	6 39 P. M.	Mar. 12	10 46 P. M.	Mar. 22	9 06 P. M.
3	12 26 A. M.	13	6 38 "	23	4 58 "
3	8 18 P. M.	15	12 25 A. M.	24	10 46 "
4	4 10 "	15	8 17 P. M.	25	6 37 "
5	9 57 "	16	4 09 "	26	12 25 A. M.
6	7 49 "	17	9 56 "	27	8 17 P. M.
7	11 36 "	18	5 48 "	28	4 08 "
8	7 28 "	19	11 35 "	29	9 56 "
9	3 19 "	20	7 27 "	30	5 47 "
10	9 07 "	21	3 19 "	31	11 35 "
11	4 59 "				

Jupiter's Satellites for March.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I.		III.	
II.		IV.	No Eclipse.

Configuration at 7h for an Inverting Telescope.

Day.	West									East.												
1			·4					3·	○			·2										·1●
2					·43·			1·	○	2·												
3					·3		·2	·4	○			·1										
4							1·	·3	○			·4										·2●
5									○			1·	2· ·3		·4							
6							2· ·1		○						·3		·4					
7								·2	○		1·			3·					·4			
8									○				·2						4·			
9	○	1·				3·			○		2·								4·			
10					·3		2·		○			·1					4·					
11								·31·	○				4·									·2●
12									4 ○				·1 ·3	2·								
13						4·		·12·	○						·3							
14					4·			·2	○			1·		3·								
15				4·				·1	○	3·			·2									
16			4·				3·		○	1·		2·										
17				·4			·3	2·	○													·1●
18					.4			·3	1·	·2 ○												
19							·4		○			·3·1	2·									
20								1·	·4	2· ○					·3							
21								·2	○			1· ·4			3·							
22								·1	○		3·	·2				4·						
23							3·		○		1·	2·						4·				
24					3·			2·	○										·4		·1●	
25							·3		·21·	○									4·			
26									○	·3	·1		·2				4·					
27	○	2·						.1	○						·3	4·						
28							·2		○			·1	4·		3·							
29								·1	4·	○		·2	3·									
30						4·		3·		○		1·	2·									
31				4·		3·		2·		·1 ○												

Phenomena of Jupiter's Satellites.

Central Time.

	h	m				h	m			
Mar. 1	12	13	P. M.	III	Tr. In.	Mar. 10	4	22	A. M.	II	Sh. Eg.
	2	21	"	III	Tr. Eg.		2	46	"	I	Oc. Dis.
	5	28	"	III	*Sh. In.		6	10	"	I	*Ec. Re.
	6	18	"	I	*Oc. Dis.	11	11	55	"	I	Tr. In.
	7	28	"	III	*Sh. Eg.		1	08	P. M.	I	Sh. In.
	9	45	"	I	*Ec. Re.		2	08	"	I	Tr. Eg.
2	3	27	"	I	Tr. In.		3	21	"	I	Sh. Eg.
	4	44	"	I	Sh. In.		5	45	"	II	*Oc. Dis.
	5	41	"	I	*Tr. Eg.		8	10	"	II	*Oc. Re.
	6	57	"	I	*Sh. Eg.		8	14	"	II	*Ec. Dis.
	8	48	"	II	*Tr. In.		10	31	"	II	Ec. Re.
	11	13	"	II	Tr. Eg.	12	6	25	A. M.	III	Oc. Dis.
	11	21	"	II	Sh. In.		8	35	"	III	Oc. Re.
3	1	44	A. M.	II	Sh. Eg.		9	15	"	I	Oc. Dis.
	12	47	"	I	Oc. Dis.		11	29	"	III	Ec. Dis.
	4	14	P. M.	I	Ec. Re.		12	39	P. M.	I	Ec. Re.
4	9	57	A. M.	I	Tr. In.		1	18	"	III	Ec. Re.
	11	12	"	I	Sh. In.	13	6	25	A. M.	I	Tr. In.
	12	10	P. M.	I	Tr. Eg.		7	37	"	I	Sh. In.
	1	26	"	I	Sh. Eg.		8	38	"	I	Tr. Eg.
	3	03	"	II	Oc. Dis.		9	50	"	I	Sh. Eg.
	5	28	"	II	Oc. Re.		12	54	P. M.	II	Tr. In.
	5	37	"	II	*Ec. Dis.		3	18	"	II	Sh. In.
	7	54	"	II	*Ec. Re.		3	19	"	II	Tr. Eg.
5	2	12	A. M.	III	Oc. Dis.		5	41	"	II	*Sh. Eg.
	4	20	"	III	Oc. Re.	14	3	45	A. M.	I	Oc. Dis.
	7	17	"	I	Oc. Dis.		7	08	"	I	Ec. Re.
	7	29	"	III	Ec. Dis.	15	12	54	"	I	Tr. In.
	9	17	"	III	Ec. Re.		2	05	"	I	Sh. in.
	10	43	"	I	Ec. Re.		3	08	"	I	Tr. Eg.
6	4	26	"	I	Tr. In.		4	19	"	I	Sh. Eg.
	5	41	"	I	Sh. In.		7	07	"	II	Oc. Dis.
	6	40	"	I	Tr. Eg.		9	32	"	II	Oc. Re.
	7	55	"	I	Sh. Eg.		9	32	"	II	Ec. Dis.
	10	10	"	II	Tr. In.		11	49	"	II	Ec. Re.
	12	35	P. M.	II	Tr. Eg.		8	41	P. M.	III	*Tr. In.
	12	40	"	II	Sh. In.		10	15	"	I	Oc. Dis.
	3	03	"	II	Sh. Eg.		10	51	"	III	Tr. Eg.
7	1	46	A. M.	I	Oc. Dis.		1	30	A. M.	III	Sh. In.
	5	12	"	I	Ec. Re.	16	1	37	"	I	Ec. Re.
	10	56	P. M.	I	Tr. In.		3	32	"	III	Sh. Eg.
8	12	10	A. M.	I	Sh. In.		7	24	P. M.	I	*Tr. In.
	1	09	"	I	Tr. Eg.		8	34	"	I	*Sh. In.
	2	23	"	I	Sh. Eg.		9	38	"	I	*Tr. Eg.
	4	24	"	II	Oc. Dis.		10	48	"	I	Sh. Eg.
	6	49	"	II	Oc. Re.	17	2	16	A. M.	II	Tr. In.
	6	55	"	II	Ec. Dis.		4	36	"	II	Sh. In.
	9	12	"	II	Ec. Re.		4	42	"	II	Tr. Eg.
	4	25	P. M.	III	Tr. In.		7	00	"	II	Sh. Eg.
	6	34	"	III	*Tr. Eg.		4	45	P. M.	I	Oc. Dis.
	8	16	"	I	*Oc. Dis.		8	06	"	I	*Ec. Re.
	9	29	"	III	*Sh. In.	18	1	54	"	I	Tr. In.
	11	30	"	III	Sh. Eg.		3	03	"	I	Sh. In.
	11	41	"	I	Ec. Re.		4	08	"	I	Tr. Eg.
9	5	25	"	I	Tr. In.		5	16	"	I	Sh. Eg.
	6	39	"	I	*Sh. In.		8	29	"	II	*Oc. Dis.
	7	39	"	I	*Tr. Eg.	19	1	07	A. M.	II	Ec. Re.
	8	52	"	I	*Sh. Eg.		10	42	"	III	Oc. Dis.
	11	32	"	II	Tr. In.		11	15	"	I	Oc. Dis.
10	1	57	A. M.	II	Tr. Eg.		12	53	P. M.	III	Oc. Re.
	1	59	"	II	Sh. In.		2	35	"	I	Ec. Re.

Mar. 19	3	30	"	III	Ec.	Dis.	Mar. 26	3	44	A. M.	II	Ec.	Re.
	5	20	"	III	Ec.	Re.		1	15	P. M.	I	Oc.	Dis.
20	8	24	A. M.	I	Tr.	In.		3	02	"	III	Oc.	Dis.
	9	32	"	I	Sh.	In.		4	30	"	I	Ec.	Re.
	10	38	"	I	Tr.	Eg.		5	14	"	III	Oc.	Re.
	11	45	"	I	Sh.	Eg.		7	31	"	III	*Ec.	Dis.
	3	39	P. M.	II	Tr.	In.		9	22	"	III	Ec.	Re.
	5	55	"	II	*Sh.	In.	27	10	24	A. M.	I	Tr.	In.
	6	05	"	II	*Tr.	Eg.		11	27	"	I	Sh.	In.
	8	19	"	II	*Sh.	Eg.		12	38	P. M.	I	Tr.	Eg.
21	5	45	A. M.	I	Oc.	Dis.		1	40	"	I	Sh.	Eg.
	9	03	"	I	Ec.	Re.		6	26	"	II	*Tr.	In.
22	2	54	"	I	Tr.	In.		8	33	"	II	*Sh.	In.
	4	01	"	I	Sh.	In.		8	52	"	II	*Tr.	Eg,
	5	08	"	I	Tr.	Eg.		10	57	"	II	Sh.	Eg.
	6	14	"	I	Sh.	Eg.	28	7	45	A. M.	I	Oc.	Dis.
	9	51	"	II	Oc.	Dis.		10	59	"	I	Ec.	Re.
	2	26	P. M.	II	Ec.	Re.	29	4	54	"	I	Tr.	In.
23	12	15	A. M.	I	Oc.	Dis.		5	56	"	I	Sh.	In.
	12	58	"	III	Tr.	In.		7	08	"	I	Tr.	Eg.
	3	09	"	III	Tr.	Eg.		8	09	"	I	Sh.	Eg.
	3	32	"	I	Ec.	Re.		12	37	P. M.	II	Oc.	Dis.
	5	30	"	III	Sh.	In.		5	03	"	II	Ec.	Re.
	7	33	"	III	Sh.	Eg.	30	2	15	A. M.	I	Oc.	Dis.
	9	24	P. M.	I	Tr.	In.		5	18	"	III	Tr.	In.
	10	30	"	I	Sh.	In.		5	28	"	I	Ec.	Re.
	11	38	"	I	Tr.	Eg.		7	30	"	III	Tr.	Eg.
24	12	43	A. M.	I	Sh.	Eg.		9	31	"	III	Sh.	In.
	5	03	"	II	Tr.	In.		11	35	"	III	Sh.	Eg.
	7	14	"	II	Sh.	In.		11	24	P. M.	I	Tr.	In.
	7	29	"	II	Tr.	Eg.	31	12	25	A. M.	I	Sh.	In.
	9	38	"	II	Sh.	Eg.		1	38	"	I	Tr.	Eg.
	6	45	P. M.	I	*Oc.	Dis.		2	38	"	I	Sh.	Eg.
	10	01	"	I	Ec.	Re.		7	50	"	II	Tr.	In.
25	3	54	"	I	Tr.	In.		9	52	"	II	Sh.	In.
	4	58	"	I	Sh.	In.		10	16	"	II	Tr.	Eg.
	6	08	"	I	*Tr.	Eg.		12	16	P. M.	II	Sh.	Eg.
	7	12	"	I	*Sh.	Eg.		8	45	"	I	*Oc.	Dis.
	11	14	"	II	Oc.	Dis.		11	57	"	I	Ec.	Re.

NOTE.—In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse. Oc. denotes occultation; Tr., transit of the satellite; Sh., transit of the shadow; * Visible at Washington.

A Partial Eclipse of the Moon will occur on March 21. It will not, however, be visible in the United States except in the extreme western part just as the Moon is setting. It will be visible in Alaska, the Pacific Ocean and Asia. At the middle of the eclipse 0.248 of the Moon's diameter will be obscured. The following are the elements of the eclipse as given by the *American Ephemeris*:

Greenwich mean time of opposition in right ascension March 21, $1^h\ 27^m\ 17^s.1$.

Sun's right ascension	0^h	03^m	$24^s.38$	Hourly motion		$9^s.10$
Moon's right ascension	12	03	24 .38	Hourly motion	120	.73
Sun's declination	0°	22′	10″.1N	Hourly motion	0′	59″.2N
Moon's declination	0	36	09 .5N	Hourly motion	16	29 .3S
Sun's equa. hor. parallax			8 .6	Sun's semi-diameter	16	02 .9
Moon's equa. hor. parallax		58	10 .5	Moon's " "	15	50 .4

TIMES OF THE PHASES:

	Gr. Mean Time. h m	Central Time. h m	Pacific Time. h m
Moon enters penumbra.....March 21,	11 57.4 A. M.	5 57.4 A. M.	3 57.4 A. M.
Moon enters shadow.....	1 25.3 P. M.	7 25.3 "	5 25.3 "
Middle of the eclipse.....	2 20.6 "	8 20.6 "	6 20.6 "
Moon leaves shadow.....	3 15.7 "	9 15.7 "	7 15.7 "
Moon leaves penumbra.....	4 43.7 "	10 43.7 "	8 43.7 "

Elongations of the Satellites of Saturn.

[In the diagram the points marked 0 are those of eastern elongation of the several satellites. Their positions at intervals of one day after eastern elongation are indicated by the symbols 1*d*, 2*d*, etc.]

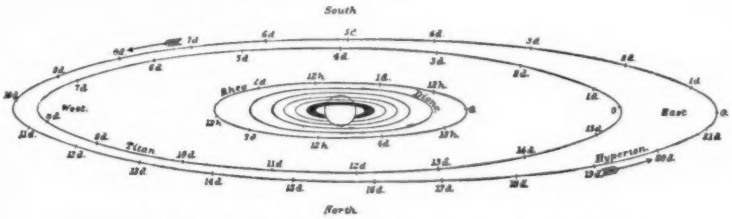


DIAGRAM OF THE APPARENT ORBITS OF SATURN'S SATELLITES.

MIMAS.

		h			
Mar.	2	3.2	A. M.	E
	3	1.8	"	E
	4	12.4	"	E
	4	11.0	P. M.	E
	9	4.8	A. M.	W
	10	3.4	"	W
	11	2.0	"	W
	12	12.6	"	W
	12	11.3	P. M.	W
	18	3.6	A. M.	E
	19	2.3	"	E
	20	12.9	"	E
	20	11.5	P. M.	E
	21	10.1	"	E
	26	3.8	A. M.	W
	27	2.5	"	W
	28	1.1	"	W
	28	11.7	P. M.	W
	29	16.3	"	W

ENCELADUS.

		h			
Mar.	1	12.0	midn.	E
	3	8.9	A. M.	E
	4	5.8	P. M.	E
	6	2.7	A. M.	E
	7	11.5	"	E
	8	8.4	P. M.	E
	10	5.3	A. M.	E
	11	2.2	P. M.	E
	12	11.1	"	E
	14	7.9	A. M.	E
	15	4.8	P. M.	E
	17	1.7	A. M.	E
	18	10.6	"	E
	19	7.5	P. M.	E

ENCELADUS Cont.

		h			
Mar.	21	4.3	A. M.	E
	22	1.2	P. M.	E
	23	10.1	"	E
	25	7.0	A. M.	E
	26	3.9	P. M.	E
	28	12.7	A. M.	E
	29	9.6	"	E
	30	6.5	P. M.	E
Apr.	1	3.4	A. M.	E

TETHYS.

		h			
Mar.	2	11.9	A. M.	E
	4	9.2	"	E
	6	6.5	"	E
	8	3.8	"	E
	10	1.1	"	E
	11	10.4	P. M.	E
	13	7.7	"	E
	15	5.0	"	E
	17	2.3	"	E
	19	11.6	A. M.	E
	21	8.9	"	E
	23	6.2	"	E
	25	3.5	"	E
	27	12.8	"	E
	28	10.1	P. M.	E
	30	7.4	"	E

DIONE.

		h			
Mar.	3	5.5	P. M.	E
	6	11.2	A. M.	E
	9	4.8	"	E
	11	10.5	P. M.	E
	14	4.2	"	E
	17	9.9	A. M.	E
	20	3.5	A. M.	E

DIONE Cont.

		h			
Mar.	22	9.2	P. M.	E
	25	2.9	"	E
	28	8.6	A. M.	E
	31	2.2	"	E

RHEA.

		h			
Mar.	2	9 9	A. M.	E
	6	10.3	P. M.	E
	11	10.7	A. M.	E
	15	11.1	P. M.	E
	20	11.5	A. M.	E
	24	11.8	P. M.	E
	29	12.2	"	E

TITAN.

		h			
Mar.	4	12.9	P. M.	W
	8	2.8	"	S
	12	9.9	A. M.	E
	16	7 4	"	I
	20	10.9	"	W
	24	12.9	P. M.	S
	28	7.9	A. M.	E
Apr.	1	5.4	"	I

HYPERION.

		h			
Mar.	5	6.7	P. M.	S
	10	10.7	"	E
	17	7.3	A. M.	I
	22	2.5	P. M.	W
	26	11.8	"	S
Apr.	1	4.0	A. M.	E

IAPETUS.

		h			
Feb.	28	1.0	A. M	W
Mar.	19	9.9	P. M.	S
Apr.	9	9.0	A. M.	E

Occultations Visible at Washington.

Date 1894.	Star's Name.	Magnitude.	IMMERSION Washington M. T.		IMMERSION Angle f'm N pt.	EMERSION Washington M. T.		EMERSION Angle f'm N pt.	Duration.	
			h	m	°	h	m	°	h	m
Mar. 16	λ Cancri	6	14	47	62	15	20	340	0	33
18	37 Leonis	6	15	49	57	16	14	1	0	25
20	β Virginis	4	10	52	173	11	49	269	0	37

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

R. A.....$0^h\ 52^m\ 32^s$
Decl.....$+81°\ 17'$
Period.....$2d\ 11^h 50^m$

Mar.		
	3	7 A. M.
	5	7 P. M.
	8	6 A. M.
	10	6 P. M.
	13	6 A. M.
	15	6 P. M.
	18	6 A. M.
	20	5 P. M.
	23	5 A. M.
	25	5 P. M.
	28	5 A. M.

ALGOL.

R. A.....$3^h\ 1^m\ 1^s$
Decl.....$+40°\ 32'$
Period.....$2d\ 20^h 49^m$

Mar.		
	6	4 A. M.
	9	1 "
	11	10 P. M.
	14	7 "
	17	3 "
	20	12 noon
	23	9 A. M.
	26	6 "
	29	3 "

λ TAURI.

R. A.....$3^h\ 54^m\ 35^s$
Decl.....$+12°\ 11'$
Period.....$3d\ 22^h\ 52^m$

Mar.		
	1	3 P. M.
	5	2 "
	9	1 "
	13	noon
	17	11 A. M.
	21	9 "
	25	8 "
	29	7 "

R CANIS MAJORIS.

R. A.....$7^h\ 14^m\ 30^s$
Decl.....$-16°\ 11'$
Period.....$1d\ 3^h\ 16^m$

Mar.		
	1	10 P. M.
	3	1 A. M.
	4	5 "
	5	8 "
	6	11 "
	7	2 P. M.
	8	6 "
	9	9 "
	10	12 midn.
	12	3 A. M.
	13	7 "
	14	10 "
	15	1 P. M.
	16	4 "
	17	8 "
	18	11 "

R CANIS MAJ., CONT.

	20	2 A. M.
	21	5 "
	22	9 "
	23	12 noon.
	24	3 P. M.
	25	7 "
	26	10 "
	28	1 A. M.
	29	4 "
	30	8 "
	31	11 "

S CANCRI.

R. A.....$8^h\ 37^m\ 39^s$
Decl.....$+19°\ 26'$
Period.....$9d\ 11^h\ 38^m$

Mar.		
	6	1 P. M.
	16	1 A. M.
	25	1 P. M.

S ANTLIÆ.

R. A.....$9^h\ 27^m\ 30^s$
Decl.....$-28°\ 09'$
Period.....$0d\ 7^h\ 47^m$

Mar.		
	1	5 P. M.
	2	12 midn.
	3	11 P. M.
	4	11 "
	5	10 "
	6	9 "
	7	9 "
	8	8 "
	9	7 "
	10	7 "
	11	6 "
	12	5 "
	13	12 midn.
	14	12 "
	15	11 P. M.
	16	11 "
	17	10 "
	18	9 "
	19	9 "
	20	8 "
	21	7 "
	22	7 "
	23	6 "
	24	5 "
	25	5 "
	26	12 midn.
	27	11 P. M.
	28	11 "
	29	10 "
	30	9 "
	31	9 "

δ LIBRÆ.

R. A.....$14^h\ 55^m\ 06^s$
Decl.....$-8°\ 05'$
Period.....$2d\ 07^h\ 51^m$

Mar.		
	1	5 A. M.
	3	1 P. M.
	5	9 "
	8	5 A. M.
	10	1 P. M.
	12	9 "
	15	5 A. M.
	17	12 noon
	19	8 P. M.
	22	4 A. M.
	24	12 noon
	26	8 P. M.
	29	4 A. M.
	31	11 "

U CORONÆ.

R. A.....$15^h\ 13^m\ 43^s$
Decl.....$+32°\ 03'$
Period.....$3d\ 10^h\ 51^m$

Mar.		
	4	1 A. M.
	7	12 noon
	10	11 P. M.
	14	10 A. M.
	17	9 P. M.
	21	7 A. M.
	24	6 P. M.
	28	5 A. M.

U OPHIUCHI.

R. A.....$17^h\ 10^m\ 56^s$
Decl.....$+1°\ 20'$
Period.....$0d\ 20^h\ 08^m$

Mar.		
	1	2 A. M.
	2	10 P. M.
	3	6 "
	4	2 "
	5	10 A. M.
	6	6 "
	7	2 "
	7	11 P. M.
	8	7 "
	9	3 "
	10	11 A. M.
	11	7 "
	12	3 "
	12	11 P. M.
	13	8 "
	14	4 "
	15	12 noon
	16	8 A. M.
	17	4 "
	17	12 midn.
	18	8 P. M.
	19	4 "
	20	1 "
	21	9 A. M.
	22	5 "
	23	1 "

U OPHIUCHI CONT.			Y CYGNI.			Y CYGNI CONT.		
Mar.	23	9 P. M.	R. A.	$20^h\ 47^m\ 40^s$		Mar.	16	2 A. M.
	24	5 "	Decl.	$+34°\ 15'$			17	2 P. M.
	25	1 "	Period	$1^d\ 11^h\ 57^m$			19	2 A. M.
	26	9 A. M.	Mar.	2	2 P. M.		20	2 P. M.
	27	6 "		4	2 A. M.		22	2 A. M.
	28	2 "		5	2 P. M.		23	2 P. M.
	28	10 P. M.		7	2 A. M.		25	2 A. M.
	29	6 "		8	2 P. M.		26	2 P. M.
	30	2 "		10	2 A. M.		28	1 A. M.
	31	10 A. M.		11	2 P. M.		29	1 P. M.
				13	2 A. M.		31	1 A. M.
				14	2 P. M.			

Test Objects for Small Telescopes.

[From Clark and Sadler's "Star Guide."]

Name of Objects.	R. A. h	m	Decl. °	′	Distance. ″	Position Angle. °	Magnitudes.		Aperture of telescope
DIVIDING TESTS.									
14 Orionis	5	02	+ 8	20	1.15	203	5.8	6.0	4
4 Lyncis	6	12	+ 59	25	0.95	101	6.2	7.5	5
Σ 1333	9	11	+ 35	56	1.69	42	6.7	7.0	3
OΣ 229	10	42	+ 41	42	0.84	330	6.5	7.5	6
Σ 1606	12	05	+ 40	32	1.21	338	6.2	7.0	4
Cor. Bor. 1	15	14	+ 27	15	1.22	308	5.6	6.1	4
μ^2 Boötis	15	20	+ 37	47	0.78 108.4	104 172	6.5 4.5	7.8 —	6
λ Ophiuchi	16	25	+ 2	14	1.65	44	4.4	5.4	3
OΣ 313	16	29	+ 40	21	0.99	152	7.0	7.6	5
Cephei 83	20	59	+ 56	13	1.62	349	6.4	6.8	3
DEFINING TESTS.									
ψ^2 Orionis	5	21	+ 2	59	2.66	324	5.4	9.0	4
42 Orionis	5	30	− 4	55	1.73	218	5.5	9.2	6
κ Leonis	9	18	+ 26	41	3.36 10.	205 65	5.1	10.1 11.5	6
49 Leonis	10	29	+ 9	14	2.39	158	6.2	8.4	3
84 Virginis	13	37	+ 4	07	3.56	234	5.7	8.0	3
6 Serpentis	15	15	+ 1	08	2.28	13	4.7	9.4	6
η Draconis	16	22	+ 61	46	5.26	142	2.8	9.0	4
68 Herculis	17	13	+ 33	14	4.41	62	5.1	10.1	5
70 Ophiuchi	18	00	+ 2	32	2.05	20	4.3	6.2	3
60 Cygni	20	57	+ 45	42	2.71	165	5.5	9.5	5
SPACE-PENETRATING TESTS.									
40 Cassiopeiæ	1	29	+ 72	27	53.3	237	6.0	10.9	5
λ Geminorum	7	12	+ 16	45	9.5	33	3.5	9.8	3
6 Cancri	8	25	+ 18	29	60.8	60	5.5	10.4	4
δ Cancri	8	38	+ 18	37	42	113	5.0	11.8	6
υ Ursæ Maj	11	12	+ 33	43	7.0	147	3.5	9.6	3
ρ Boötis	14	27	+ 30	52	53	334	3.6	11.7	6
5 Ursæ Min	14	28	+ 76	12	56.4	129	4.8	10.5	4
5 Serpentis	15	13	+ 2	13	10.7	38	4.8	10.0	3
54 Ophiuchi	17	29	+ 13	15	21.6	75	6.0	11.0	5
110 Herculis	18	41	+ 20	26	61.2 44.7	96 92	5.0	12.0 11.0	6

Meteor.—On the evening of December 30th, a meteor of unusual interest was observed by two Des Moines men. It was first seen a little west of south, at an altitude of about 35°. It appeared to move slightly east of north, and stopped in the northwest, at a somewhat lower altitude than it started. The first appearance was of a bright silvery hue, resembling a streak of lightning. The luminous train remained visible while they walked more than three blocks—fully five minutes.

W. A. C.

Comparison Stars for Variables of Long Period.*

S Boötis.

Des.	R. A. 1900 h	m	Dec. 1900 °	′	Mag.
a	14	18.6	+ 53	59	7
b	14	24.0	+ 53	45	8
c	14	22.3	+ 54	10	8
d	14	12.4	+ 53	56	9
e	14	21.5	+ 53	32	9
f	14	21.0	+ 53	55	10
g	14	19.8	+ 54	1	10
h	14	18.9	+ 54	21	11
k	14	22.4	+ 54	17	11
l	14	21.7	+ 54	13	12
m	14	19.4	+ 54	20	12
n	14	19.8	+ 54	11	12
o	14	19.3	+ 54	19	13
p	14	19.3	+ 54	23	14
q	14	19.1	+ 54	18	14
r	14	19.5	+ 54	10	14
s	14	19.9	+ 54	17	15
S	14	19.5	+ 54	16	var.

R Camelopardi.

a	15	1.6	+ 84	20	8
b	14	21.4	+ 84	24	8
c	14	32.3	+ 84	10	9
d	14	46.8	+ 84	17	9
e	14	31.2	+ 84	34	10
f	14	45.8	+ 84	14	10
g	14	30.8	+ 84	15	11
h	14	28.8	+ 84	23	11
k	14	17.8	+ 84	29	12
l	14	31.3	+ 84	21	12
m	14	22.5	+ 84	16	13
n	14	13.3	+ 84	12	13
o	14	18.8	+ 84	17	14
p	14	24.2	+ 84	11	14
q	14	26.5	+ 84	12	14
r	14	26.6	+ 84	14	15
R	14	24.9	+ 84	17	var.

R Ursæ Minoris.

a	16	31.3	+ 73	9	8
b	16	35.2	+ 72	11	8
c	16	34.8	+ 73	9	9
d	16	33.6	+ 72	44	9
e	16	33.2	+ 72	40	10
f	16	28.7	+ 73	1	10
g	16	34.9	+ 72	46	10
h	16	33.6	+ 72	22	11
k	16	34.9	+ 72	20	11
l	16	31.0	+ 72	14	12
R	16	31.3	+ 72	29	var.

R Draconis.

a	16	28.1	+ 67	16	7
b	16	34.0	+ 68	13	7
c	16	25.0	+ 67	16	7
d	16	42.9	+ 68	17	8
e	16	40.8	+ 67	9	8
f	16	33.2	+ 66	55	8

R Draconis Cont.

Des.	R. A. 1900 h	m	Dec 1900 °	′	Mag.
g	16	30.2	+ 67	34	1
h	16	29.6	+ 67	1	9
k	16	31.0	+ 66	56	09
l	16	29.9	+ 67	27	10
m	16	31.4	+ 67	6	10
n	16	32.8	+ 66	49	11
o	16	32.4	+ 66	48	12
p	16	34.2	+ 66	59	12
q	16	32.6	+ 66	55	12
r	16	33.5	+ 66	57	12
s	16	33.3	+ 66	50	13
t	16	34.2	+ 67	1	14
u	16	32.6	+ 66	56	14
w	16	32.6	+ 66	59	14
x	16	32.6	+ 67	0	15
R	16	32.4	+ 66	58	var.

S Cygni.

a	20	2.6	+ 57	20	8
b	20	7.0	+ 58	2	8
c	20	1.4	+ 57	32	9
d	20	3.5	+ 57	43	9
e	20	2.3	+ 57	44	10
f	20	3.0	+ 57	40	10
g	20	4.3	+ 57	37	10
h	20	3.6	+ 57	32	11
k	20	3.8	+ 57	36	11
l	20	3.6	+ 57	40	11
m	20	3.5	+ 57	48	12
n	20	3.6	+ 57	49	13
o	20	3.6	+ 57	45	13
p	20	3.5	+ 57	39	14
q	20	2.8	+ 57	47	14
r	20	3.6	+ 57	43	14
s	20	3.8	+ 57	41	15
t	20	3.6	+ 57	43	15
S	20	3.4	+ 57	42	var.

T Cephei.

a	21	40.5	+ 70	50	5
b	20	41.9	+ 66	18	6
c	21	5.8	+ 71	2	6
d	21	0.4	+ 67	51	7
e	21	0.4	+ 67	47	7
f	21	14.3	+ 67	56	8
g	21	11.9	+ 67	44	8
h	21	6.1	+ 68	12	8
k	21	3.7	+ 67	35	9
l	21	5.7	+ 68	15	9
m	21	10.0	+ 68	1	10
n	21	9.1	+ 68	8	10
o	21	6.6	+ 68	8	10
p	21	7.2	+ 68	4	10
q	21	7.6	+ 68	12	11
r	21	6.4	+ 68	2	12
s	21	10.7	+ 68	12	12
t	21	9.7	+ 68	14	12
T	21	8.2	+ 68	5	var.

* See Plate accompanying Mr. Parkhurst's article on Variable Stars.

S CEPHEI.

Des.	R. A. 1900 h	m	Dec. 1900 °	′	Mag.
a	21	29.9	+ 77	30	7
b	21	50.9	+ 77	18	8
c	21	47.1	+ 78	34	8
d	21	52.7	+ 77	52	9
e	21	37.8	+ 78	37	9
f	21	28.7	+ 78	53	9
g	21	34.3	+ 78	1	10
h	21	34.3	+ 78	11	10
k	21	40.7	+ 78	11	10
l	21	42.2	+ 78	13	11
m	21	36.2	+ 78	4	12
n	21	39.1	+ 78	13	12
o	21	35.0	+ 78	8	12
p	21	37.5	+ 78	14	13
q	21	38.8	+ 78	4	14
r	21	37.8	+ 78	11	14
s	21	37.4	+ 78	10	14
t	21	37.7	+ 78	10	15
S	21	36.5	+ 78	10	var.

R CASSIOPELÆ.

a	23	32.6	+ 45	56	4
b	23	35.5	+ 43	46	4
c	23	53.9	+ 55	12	5

R CASSIOPELÆ CONT.

Des.	R. A. 1900 h	m	Dec. 1900 °	′	Mag.
d	0	5.1	+ 45	31	5
e	23	52.1	+ 55	9	6
f	23	56.3	+ 49	25	6
g	23	53.1	+ 49	53	7
h	23	54.5	+ 50	17	7
k	23	54.2	+ 49	58	8
l	23	54.3	+ 49	57	8
m	23	53.9	+ 51	16	9
n	23	53.5	+ 50	46	9
o	23	53.0	+ 50	41	10
p	23	54.1	+ 50	52	10
q	23	53.8	+ 50	45	10
r	23	53.3	+ 50	50	11
s	23	54.1	+ 50	48	11
t	23	53.1	+ 50	54	12
u	23	53.5	+ 50	48	12
w	23	53.2	+ 50	53	12
x	23	53.7	+ 50	54	13
y	23	53.4	+ 50	51	13
z	23	53.3	+ 50	52	14
α	23	53.4	+ 50	49	14
β	23	53.2	+ 50	49	15
R	23	53.3	+ 50	50	var.

Errata in January number:

Page 236, last line, for H. A. Parkhurst read J. A. Parkhurst. Page 237 for Casiopeiæ read Cassiopeiæ. Page 237, S Cassiopeiæ star c for Decl. 77° 52′ read Decl. 71° 52′. Page 237 S Cassiopeiæ star y for R. A. 1^h 125^m read 1^h 12.5^m. Page 237 3rd line from top for Decl. 1800 read Decl. 1900.

PRACTICAL SUGGESTIONS.

Persons interested in the topics appropriate to this corner are requested to write briefly and frequently for it.

13. Why do Astronomers think that the white spots about the poles of the planet Mars are snow or ice? G. B. D.

Answer: In connection with this question it was noted by the querist that the telescope shows a change in size of these white patches during the seasons of winter and summer on the planet Mars. This is the main reason why it is thought that the patches consist of ice and snow. It might be added that some good observers have seen indications on the surface of the planet that might be explained by supposing that a fall of snow had covered a considerable area. No astronomer would feel himself justified from his observations, or what he knows of the surface of the planet, in assigning snow or ice as the cause of these white spots. Other plausible reasons could be assigned. Some observers have intimated that clouds in the planet's atmosphere might produce the appearance observed. This explanation does not seem as satisfactory as the former one.

14. From appearance in observation the atmosphere on Mars contains less clouds than that of the Earth. If capacity for heat depends on the vapor in the atmosphere, how is it that the temperature of the planet's surface seems so high compared to that of the Earth, notwithstanding its greater distance from the Sun? G. B. D.

Answer: We are not aware that observers are agreed, or generally think, that clouds are less in the atmosphere of Mars than in our own. That would be an impossible thing to determine by observation at the distance of Mars if we

remember that our clouds do not run probably much above two miles in height on the average, except, as it might be inferred, that certain changes in color of surface markings are due to the presence of clouds. It is probable that the density of the atmosphere of Mars is less than that of the Earth, the spectroscope also indicates that there is watery vapor in the atmosphere of Mars. From all that is known, or may be fairly inferred by analogy, we would say the temperature of Mars ought to be much lower than that of Earth. But if appearances are not misleading, water on its surface does not freeze except in the region of the poles. If Earth were viewed from Mars, it is plain that the polar white caps would be much larger than those of Mars are.

Astronomers do not give any reason for this unexpected difference in surface temperature on the planets. There is no known explanation.

15. I believe Goodsell Observatory of Carleton College is one of the oldest, west of the Mississippi. When was it founded? M. W.

Answer: If memory serves us rightly some other Observatories antedate Goodsell Observatory. This observatory was built in the summer of 1877. It began its public time service in October of the same year. The first electrical time signal was sent out at noon October 23, 1877.

16. As Venus has been approaching the Earth and growing brighter with less and less illuminated disc turned towards us ever since the time of superior conjunction with the Sun last June, why are we not to expect the maximum brilliancy at its inferior conjunction (Feb. 16.) instead of about Jan. 10. W. B. H.

Answer: Because after Jan. 10 the decrease of the illuminated portion of the disc will be more rapid than the apparent increase in area, due to the approach of the planet to the earth. If the reader will refer to the diagram on page 228 (January number) he will see that for the last two months Venus has been approaching the earth rapidly and turning the illuminated half away but slowly. During January the rate of approach to the Earth diminished greatly, while the illuminated half of the disc was turned away more and more rapidly.

17. In the planet notes in the December number of POPULAR ASTRONOMY it is said that the brilliancy of Venus on Jan 10. is 218 as compared with 145 on Dec. 1. What do these numbers mean? A. E. R.

Answer: The unit of light for a planet is the amount of light received by an eye from a circular disc with same albedo, or reflecting power, as the planet, subtending an angular radius of one second of arc, situated at the Earth's distance from the Sun, and illuminated by the latter as the disc of the planet is illuminated. The light of the planet on Dec. 1. was equal to that from 145 such discs, and that on Jan. 10 to the light from 218 discs thus illuminated. On March 1 the brilliancy of Venus will be 107, and on March 22 it will be 204 on the same scale.

18. If practical will you kindly describe process, through POPULAR ASTRONOMY for photographing celestial bodies with a kodak and visual telescope? S.

Answer: We fear that the lens of a kodak will be too small to be of use in photographing stars. As to the process of using a camera with a visual telescope we can do no better than refer to the article "Astronomy with the Small Camera," by H. C. Wilson in our first number.

19. How may an observer determine longitude on the Sun? S.

Answer: It would take a long article to answer this query, and we have one in course of preparation. For the present we will say that the period of rotation of the Sun, as adopted at Greenwich is 25.38 days. The heliographic longitude of the center of the Sun's disc therefore changes (diminishes) on an average

13° 12′ each day. According to the reckoning usually adopted the longitude of the Sun's center on Jan. 1, 1894, at noon central time, was 280° 20′. On Feb. 1, at noon it will be 232° 07′, Feb. 5, 179° 27′, Feb. 10, 113° 37′, etc. Spots at the center of the Sun's disk on these dates will have the longitudes noted, those west of the center greater, those east less longitudes.

20. (1). Please give a few tests for dividing and penetrating powers of a four inch glass with power 72. (2). Ought it to show any moons of Uranus? (3). How many of Saturn? (4). How many stars ought it to show in the trapezium of Orion? S.

Answer: (1). See table "Test objects for small Telescopes" elsewhere in this number. (2). No. (3). Five; Japetus, Titan, Rhea, Tethys and Dione. (4). Five; possibly the sixth on best nights.

21. What sized prism having an angle of 90° would be required for a spectroscope with ¾-inch lenses? W. J. T.

Answer: A single prism of glass with a refracting angle of 90° will not transmit light. A compound prism, with 90° prism of flint glass and two crown glass prisms of, say, 20° each, would have to measure about 2 inches on the face of the flint glass, or 2.83 inches on the base. A 60° single prism for the same spectroscope should have a face of about 1½ inch. In either case the height, measured along the refracting edge, need not much exceed ¾ inch. Smaller prisms may be used if the loss of a little light is not of much consequence. J. E. K.

GENERAL NOTES.

Jena Discs.—Mr. J. A. Brashear has secured the beautiful 23-inch discs which were exhibited by the Jena Optical Glass makers at the Columbian Exposition, and will proceed to make an objective from them which will be at the command of astronomers desiring such an objective.

We are pleased to call attention to a brief article by Miss Armitage of New York City on the benefits of a public Observatory. The idea is an excellent one. If the great dailies of America's great city would unitedly take hold of this matter, great things worthy of a good cause would speedily follow.

Venus by Daylight.—Mr. W. Dearden of Trinidad, Colorado, writes that Venus is very easily seen as it crosses the meridian of that place.

No new comets have been discovered since October of last year. Brooks comet *c* 1893 is still visible in our 16-inch telescope but is very faint and probably out of the reach of amateurs.

Holmes' comet 1892 III has just past opposition but so far as we know has not been seen. When last seen nearly a year ago it was very faint and diffuse and unless a new outburst like that in January 1893 should occur there will be no hope of seeing it now. On the night of Jan. 12, 1894 we took a photograph of the region in which the comet should be, giving an exposure of an hour with the new 6-inch camera. There is a slightly oval stain, 20′ in diameter, on the negative, just where the comet ought to be. It has no central condensation and is so suspiciously like a dirty water stain that we hesitate to say anything about it without verification, which last is impossible until the Moon is out of the way.

Face of the Sky.—Inasmuch as the appearance of the sky for February is presented in chart form in the present number, it is unnecessary to publish a descriptive article on that subject as has been done in the earlier numbers.

Changes in Tables of Phenomena.—So many of our foreign subscribers have requested that we change the tables of phenomena so as to include their localities, that we have this month tried to give all of those phenomena whose times of occurrence are absolute, that is, independent of the position of the observer.

It would be manifestly impossible to give the Central Standard times or Greenwich times of the rising and setting of the planets for all places, since these depend upon the horizon of the observer. Our tables give the local (not Standard) times of rising and setting for Goodsell Observatory, latitude 44° 27′.7, and will answer practically for all places within 10° of the same latitude. The reader has simply to apply the difference between local and standard time at his own place adding this difference if west, substracting if east of the standard meridian, the time of which is used.

The times of occultations cannot be given except for very small districts, the parallax of the Moon being so great that a change of only a few miles will materially change the times of beginning and ending. The data for computing the times of occultations are given in any of the national nautical almanacs. Those who wish to make a specialty of observing occultations will do well to get one of these almanacs, the *American Ephemeris*, the *Nautical Almanac*, *Connaissance de Temps*, *Berliner Jahrbuch*, *Annuaire de Bruxelles*, etc.

All the other phenomena we will give in Central Standard time of the United States which is just 6 hours less than Greenwich time. In the United States the reader has to add or substract one or two hours, according as he uses Eastern, Mountain or Western time. Foreign readers will add 6 hours to obtain Greenwich time, then subtract their longitude if reckoned west, add if reckoned east from Greenwich.

Gold Medal for Professor Burnham.—Cablegrams from London announce the award of the Gold Medal of the Royal Astronomical Society to Professor S. W. Burnham of the University of Chicago for his discoveries and micrometrical measures of double stars and for his researches on the orbital motions of Binary Systems. This news is especially welcome to American astronomers, and will be favorably received throughout the scientific world, for no observer either living or dead has contributed more to this important branch of modern astronomy than has Professor Burnham, whose discoveries of new and very close pairs have created an epoch in the history of Double Star Astronomy. The discovery of double stars, begun by Sir William Herschel more than a century ago, and since continued by William and Otto Struve, Herschel and Mædler, Dawes and Dembowski, was regarded twenty-five years ago as practically exhausted. But the genius of Burnham working with only a six-inch telescope soon brought to light hundreds of close pairs never before detected, and opened the way to later discoveries of priceless value. Professor Burnham afterwards secured for a time the use of the Dearborn 18-inch refractor, and the Madison 15-inch, and thus extended the list of measures and new discoveries. His work at the Lick Observatory is too recent to need recalling to the readers of this Journal, but it may not be inappropriate to remark that his own stars now number nearly 1300, and include the most rapid and interesting pairs in the heavens.

It is understood that these stars will be made the object of special attention at the Yerkes Observatory, and that they will be carefully followed until their orbits are accurately known. Professor Burnham's catalogue of his new stars and his general catalogue of all the important stars in the northern hemisphere are to be printed among the first volumes issued by the Yerkes Observatory, and will constitute works on Double Star Astronomy which are destined to be "aere perennius."

The high honor conferred upon Professor Burnham is a tribute to pure science which will be fully appreciated by all American astronomers, but it is especially gratifying to the intimate friends of this modest, unselfish and renowned observer.

Other American astronomers who have received this Medal of recent years are:—Professor Simon Newcomb, Professor Asaph Hall, Dr. B. A. Gould, Professor E. C. Pickering, and Dr. G. W. Hill. Last year the Gold Medal was awarded to Dr. H. C. Vogel, and the preceding year to Professor G. H. Darwin.

A Public Observatory for Boston.—The Boston *Transcript*, Jan. 10, gives an account of a meeting of the Boston Scientific Society which has just been discussing the advisability of building a public Observatory. Mr. J. Ritchie favors it. So also P. S. Yendell, E. F. Sawyer, and A. Lawrence Rotch, who briefly noted the present status of "Urania" in Berlin.

Dr. S. C. Chandler presented a paper, the line of argument being that an institution of that nature would have its value as a scientific missionary feature. An important consideration is the encouragement and stimulation of beginners, who have not at the present time the opportunity to enter the domain of astronomy.

In his opinion, if this object could be accomplished, it would be the noblest outcome of such an institution. The astronomer has a distinct duty towards the informed, intelligent citizens, whose sole means of getting proper ideas lie in popular lectures and statements, who should not be misled by information from those institutions or lecturers, where popular reputation is unworthily valued above the esteem of scientific men and real value in work. Dr. Chandler expressed it as his opinion that in competent hands, with a moderate expenditure, not only could the public taste in this department be appeased, but the science of astronomy could be advanced in a way which is very much needed, for the astronomy of this country is peculiar.

Properly organized and administered, it would be a lasting credit to this community. That it could be so organized and economically administered, if it had a moderate endowment, he thought there could be no reasonable doubt, and no more worthy way in which a popular want could be met and science benefited than by a financial provision for its needs, small indeed when compared with the amounts frequently lavished in other directions for the encouragement of science and the arts in our native city.

Remarkable Sun Spots.—Mr. Martin Winger of Brooklyn Village, Ohio, has given us the following list of remarkable sun spots.

Jan. 21st, 1892, Visible with naked eye.
Feb. 5th, 1892, " " " "
Feb. 10th, 1892, " " " "
Jan. 21st, 1893, Visible in opera-glass.
Feb. 5th, 1893, " " "
Feb. 25th, 1893, " " "
Aug. 9th, cluster of spots plainly seen with naked eye.
Also, Aug. 19th and 30th, Sept. 3rd, 4th, 6th and 28th. Oct. 12th to 19th large spots were observed with 4½-inch Clark telescope. Oct. 24th and 25th spots visible with naked eye. Dec. 7th and 8th spots plainly seen with field-glass.

Jupiter's Satellites in 1664.

I have brought to the notice of three astronomers an interesting letter of John Winthrop (the second of that name), written in 1664 to Sir Robert Moray, in which Winthrop declares that, "having looked upon Jupiter with a telescope," August 6, 1663 (old style), he "saw five satellites very distinctly about that planet." He reports the observation with natural distrust, lest it shonld be "a mistaken novelty." As the letter (which is printed in the Proceedings of the Massachusetts Historical Society for June, 1878, p. 220) had never been noticed by the three astronomers above mentioned, I make the following extract from it for the entertainment of other scientific antiquaries among your readers. If any one knows what has become of Winthrop's astronomical "tube," perhaps he will inform you.—Yours respectfully, D. C. GILMAN.

JOHN HOPKINS UNIVERSITY,
Baltimore, Md , December 22, 1893.

JOHN WINTHROP TO SIR ROBERT MORAY.

HARTFORD, Jan: 27, 1664.

In my former I gave your honor an account of the favor I had of your letter by the Hon. Colonell Richard Nicolls. I then omitted to acquaint your honor what now I will be bold to add: that havinge looked upon Jupiter with a Telescope, upon the 6th of August last, I saw 5 (?) Satellites very distinctly about that Planet: I observed it with the best curiosity I could, taking very distinct notice of the number of them, by severall aspects with some convenient tyme of intermission; & though I was not with out some consideration whether that fifth might not be some fixt starr with which Jupiter might at that tyme be in neare conjunction, yet that consideration made me the more carefully to take notice whether I could discerne any such difference of one of them from the other foure, that might by the more twinckling light of it or any other appearance give ground to believe that it might be a fixed starr, but I could discerne nothing of that nature: and I consider that the tube with which I looked upon them, though so good as to shew very clearely the Satellytes, yet was but of 3 foote and halfe with a concave ey-glasse; and I question whether by a farre better tube a fixt star can be discerned so near the body of that planet when in the ever bright activity of its light, for if so, why are there not often if not alwayes seene with the best tubes the like or more. Is not Jupiter often in neere conjunction with them, especially *in via lactea*?

I have been in much doubt whether I should mention this, which would possibly be taken from a single affirmation but a mistaken novelty; but I thought I would rather beare such sensure than omit the notice of it to such worthy friends as might from the hint of it take occasion to cause more frequent observations to be made upon that planet, & at least this will at length be cleared, whether the light of Jupiter doth not take away the appearance of fixed starrs so neere in conjunction with it, as that they should appear within the periphery of that single *intuitus* by a tube which taketh in the body of Jupiter and that at the same unmoved aspect: and I am bold the rather to mention this as an inquiry whether any such number of Satellites or Moons hath beene seene by your honor or Mr. Rooke or any mathematitians or other gentlemen that have good tubes and often have the curiosity to view the planet, for possibly it may be new to me which hath beene more usually knowne by others, though the notion of such a thinge is not new to my selfe, for I remember I mett with the like narration many years since in a little booke intituled Philosophia Naturalis per Joh. Phociliden, though then I thought that was but a mistake of some fixed starrs."—*Nation*, Jan. 11, 1894.

Yerkes Telescope.—Special attention is called to the plate accompanying Mr. Brashear's article. It is of general interest in that it shows the evolution of a telescope lens, and of special interest as it is the great lens known and talked of the world over.

PUBLISHER'S NOTICES.

Correspondents will please exercise care in the preparation of manuscript for publication. All should be plainly written, especially in the case of proper names. All remittances should be sent to Miss Charlotte R. Willard, Observatory of Carleton College, Northfield, Minnesota, U. S. A. Matter for publication may be sent either to Miss Willard, or to William W. Payne, publisher, of same address.

The accompanying star-map is one of a series to follow, arranged especially for this publication. It is copied, by permission, from Messrs. Poole Brothers' excellent Planisphere, which we have described and illustrated in other numbers of this publication.*

This Planisphere so well pleased Professor Winslow Upton, Director of the Ladd Observatory of Brown University, Providence, R. I., that he suggested to the publisher of this journal the use of it to illustrate his articles on the study of Constellations, the first of which appeared in the initial number of this magazine, dated September, 1893. Professor Upton's plan in its details seemed so feasible and desirable that it was at once submitted to Messrs. Poole Brothers of Chicago, and the result of the interview was that they not only granted us the use of the Planisphere for this purpose, but also gave us many valuable suggestions in adapting it in detail to carry out Professor Upton's wishes, and to meet the wants of teachers and amateurs in reference to, and actual study of, the constellations.

These carefully prepared star-charts seem the best adapted for the work proposed of any we know of. They were selected after months of thought and correspondence. The publisher is pleased to acknowledge the great assistance rendered by Messrs. Poole Brothers in bringing out this series of popular star-charts.

Little need be said by way of explanation of the accompanying map in addition to what Professor Upton has given in his article, published elsewhere in this number. The map shows the sky as seen February 15th, 9 o'clock P. M., which, of course, equals 8 o'clock P. M. February 1st; equals 10 o'clock P. M., February 28th, nearly. Succeeding numbers will have similar maps adapted similarly, for the following months until nearly the entire Celestial Sphere has been shown.

It is also part of the plan of Dr. H. C. Wilson, who is so efficiently editing the phenomenal notes and tables for both of our publications, to present on these star-charts, from month to month, the paths of the planets, comets and other similar phenomena which can be so represented in colored ink, for the sake of ready and general reference.

This chart is placed in the back part of the number so that it may be easily referred to while reading any article in the magazine, for when the chart is unfolded it is wholly outside of the ordinary page.

If any one desires to study the constellations and other easy celestial phenomena belonging to other parts of the heavens, the Poole Planisphere and Handbook will be found very useful guides.

Agents for Popular Astronomy. The publisher would like to call the attention of young people generally who are interested in astronomy to the merits of this new publication. In the later numbers [this one in particular] we are reaching what we want to do more nearly than was shown in earlier ones. Any person who will act as agent will be furnished copies of the publication, for specimens, free of charge, and such a commission offered as can be afforded. We are sure there is a field for work in connection with high schools and colleges having courses in astronomy, and also in cities where observatories are located. Our subscription lists already indicate this. Correspondence is solicited.

Popular Astronomy has on its lists paid subscriptions from *five* continents representing *thirteen* different countries. Although the territory seems large, the number of subscribers is not yet as large as looked for at this time. Descriptive circulars will be sent to any one interested, and it is hoped that they may be used freely.

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* See September number, 1893, p. 48 and advertising pages.

MAP OF THE
CONSTELLATIONS
VISIBLE FEBRUARY 15,
AT 9. P. M.

REDUCED FROM SECTION OF
POOLE BROTHERS' PLANISPHERE.

BY PERMISSION.

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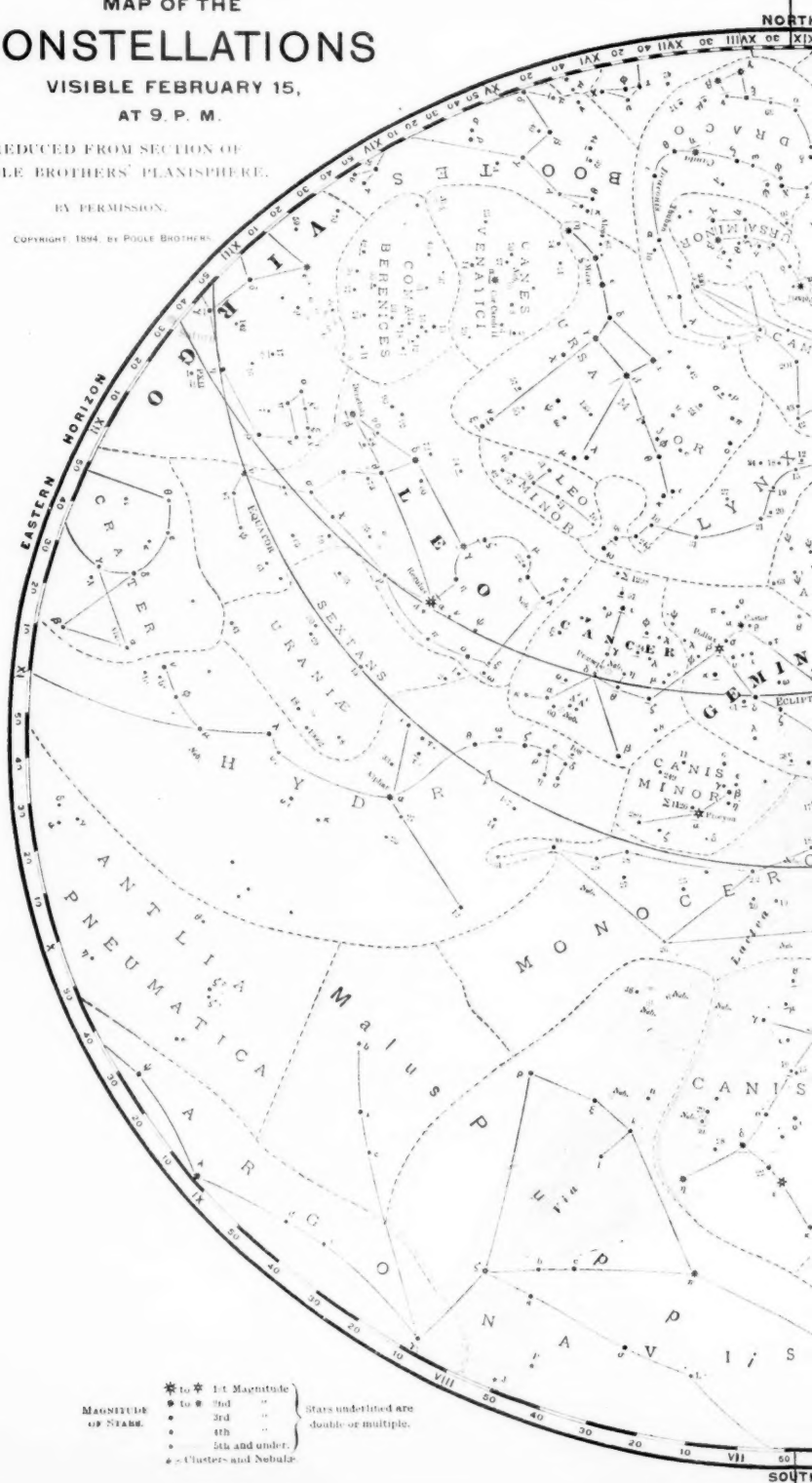
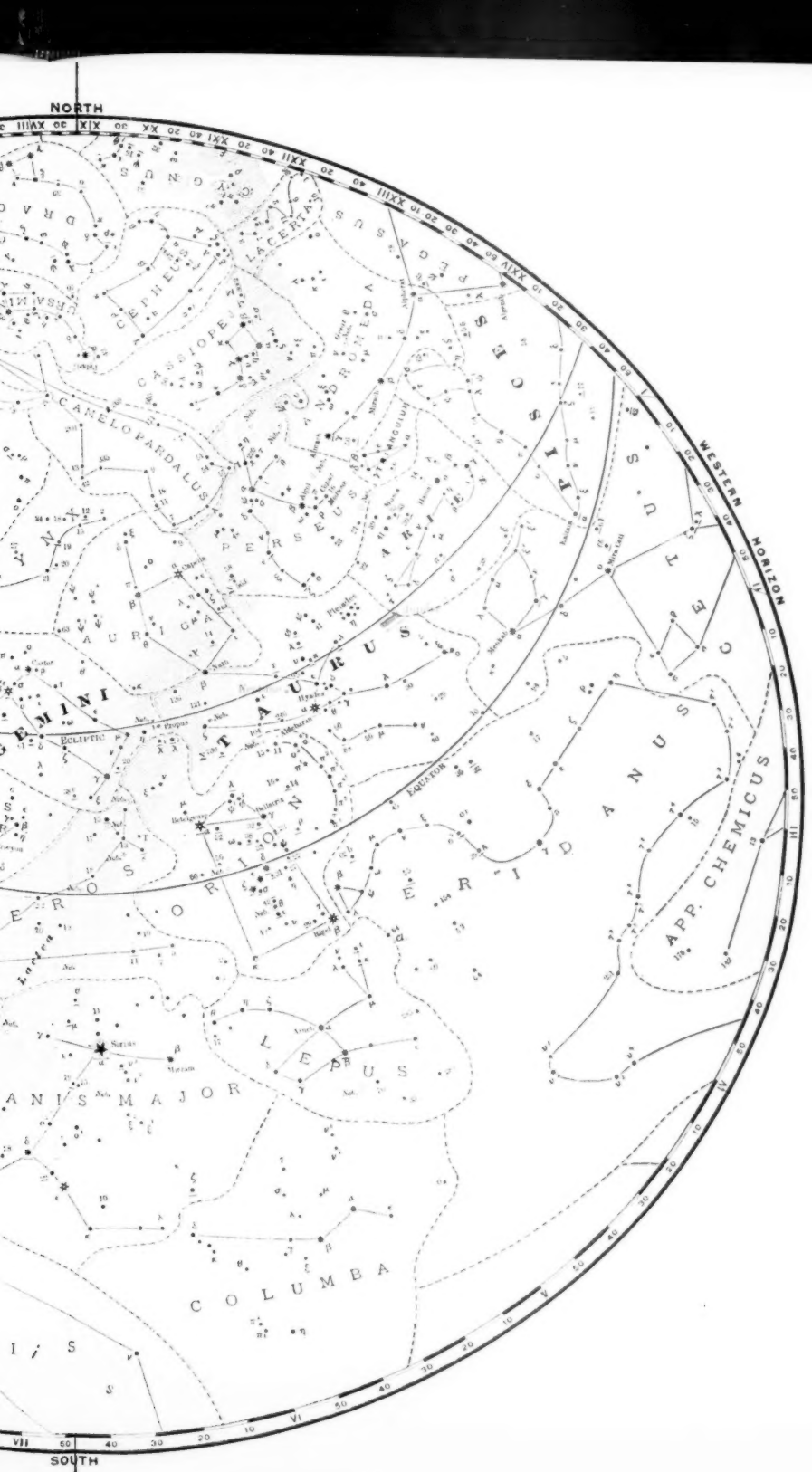


MAGNITUDE OF STARS.	✱ to ✱ 1st Magnitude	Stars underlined are double or multiple.
	✱ to ✱ 2nd "	
	● 3rd "	
	● 4th "	
	● 5th and under.	

✱ = Clusters and Nebulæ.


NORTH
WESTERN HORIZON
SOUTH
EQUATOR
ECLIPTIC
CAMELOPARDALUS
CASSIOPEIA
CEPHEUS
LACERTA
PERSEUS
ANDROMEDA
TRIANGULUM
ARIES
PISCES
AURIGA
TAURUS
GEMINI
ORION
ERIDANUS
APP. CHEMICUS
LEPUS
CANIS MAJOR
COLUMBA